back of the town of Hanging Rock, which is three miles below Ironton, in Lawrence county. The first furnace in the Ohio part of the Hanging Rock district was Union furnace, situated a few miles northwest of Hanging Rock, built in 1826 and 1827 by John Means, John Sparks, and James Rodgers, the firm's name being James Rodgers & Co. Franklin furnace was the second on the Ohio side. It stood sixteen miles east of Portsmouth and half a mile from the Ohio river, in Scioto county, and was built in 1827 by the Rev. Daniel Young and others. The next furnace was Pine Grove, on Sperry's fork of Pine creek, back of Hanging Rock, and five miles from the Ohio river, in Lawrence county, built in 1828 by Robert Hamilton and Andrew Ellison. In the same year Scioto furnace, in Scioto county, fifteen miles north of Portsmouth, was built by William Salters. From this time forward blast furnaces increased rapidly on the Ohio side of the district, as well as on the Kentucky side. From 1826 to 1880 the whole number built on the Ohio side was about sixty, and on the Kentucky side about thirty. All of the early furnaces were built to use charcoal, but timber becoming scarce coke was substituted at some of them, while others were abandoned. In late years a few furnaces have been built in the district expressly to use coke or raw coal. In 1880 there were on the Ohio side thirty-one charcoal furnaces and seventeen bituminous coal or coke furnaces.

At Vesuvius furnace, on Storm's creek, in Lawrence county, Ohio, six miles northeast of Ironton, the hot-blast was successfully applied in 1836 by John Campbell and others, William Firmstone putting up the apparatus.

The Hanging Rock district, on both sides of the Ohio, has produced many eminent ironmasters, and its iron resources have been developed with great energy. Most prominent among its ironmasters of the generation now passing away are John Campbell, of Ironton, and Thomas W. Means, of Hanging Rock. Mr. Campbell, who is a native of Brown county, Ohio, was born in 1808. In connection with others he has built eleven furnaces in the Hanging Rock district. He projected the town of Ironton and gave it its name, and also assisted in the founding of Ashland, Kentucky, and in building its railroad. Like most of the ironmasters of this district he is of Scotch-Irish extraction, his ancestors having removed in 1612 from Inverary, in Argyleshire, Scotland, to the neighborhood of Londonderry, in Ulster, Ireland. Their descendants removed in 1729 and 1739 to Augusta county, Virginia; thence, in 1790, to Bourbon county, Kentucky; and thence, in 1798, to that part of Adams county, Ohio, which is now embraced in Brown county. Mr. Means was born in South Carolina in 1803, and is also of Scotch-Irish origin. His father, John Means, was an owner of one of the furnaces and forges in Adams county, Ohio. He was born in Union district, South Carolina, on March 14, 1770, and moved to Adams county, Ohio, in 1819, taking with him his slaves, whom he liberated. He died on his farm near Manchester, in Adams county, on March 15, 1837, and was buried in the churchyard in Manchester. Andrew Ellison, Robert Hamilton, James Rodgers, and Andrew Dempsey, now deceased, were enterprising and prominent iron manufacturers. In December, 1844, Mr. Hamilton successfully tried the experiment of stopping Pine Grove furnace, which he then owned, on Sunday, and his example has since been generally followed in the Hanging Rock region. This furnace is still active. John Campbell, Robert Hamilton, and Thomas W. Means were united in marriage with members of the Ellison family. The third generation of this family is now engaged in the iron business of southern Ohio.

In 1833 a forge was built at Hanging Rock, after which it was named, to manufacture blooms. It was owned by J. Riggs & Co., and was built under the superintendence of John Campbell and Joseph Riggs. A rolling mill was added before 1847. Both the forge and rolling mill have long been abandoned. A forge was built at Sample's Landing, fifteen miles below Gallipolis, soon after 1830, to make blooms for the Covington rolling mill. Bloom forge was built at Portsmouth, in Scioto county, in 1832, and in 1857 a rolling mill was added. A forge called Benner's, on Paint creek, near Chillicothe, in Ross county, once owned by James & Woodruff, was abandoned about 1850. There never were many forges in Ohio for refining iron, and there have been few, if any, for making bar iron directly from the ore. The first iron enterprises in the state preceded by only a few years the building of rolling mills at Pittsburgh.

The Globe rolling mill was built at Cincinnati in 1845. Joseph Kinsey writes us that it "was the first built in Cincinnati for the purpose of making general sizes of merchant iron, hoops, sheets, and plates. It was built by William Sellers and Josiah Lawrence, and was considered a great enterprise at that time. Soon afterwards a wire mill was added for the purpose of making the first wire used for the lines of telegraph extending through this country."

The foregoing details relate to what may be termed the charcoal era of the Ohio iron industry. The second stage in the development of the iron industry of this state dates from the introduction in its blast furnaces of the bituminous coal of the Mahoning valley in its raw state. This coal is known as splint, or block, coal, or as Brier Hill coal, from a locality of that name near Youngstown where it is largely mined. The first furnace in Ohio to use the new fuel was built expressly for this purpose at Lowell, in Mahoning county, in 1845 and 1846, by Wilkeson, Wilkes & Co., and it was successfully blown in on the 8th of August, 1846. The name of this furnace was Mahoning. A letter from John Wilkeson, now of Buffalo, New York, informs us that William McNair, a millwright, was the foreman who had charge of its erection. It was blown in by John Crowther, who had previously had charge of the furnaces of the Brady's Bend Iron Company, at Brady's Bend, Pennsylvania. Mr. Wilkeson and his brothers had for many years been prominent charcoal-iron manufacturers on the Western Reserve. They are of Scotch-Irish extraction. Their father was a native of Carlisle, Pennsylvania.

Immediately after the successful use of uncoked coal in the furnace at Lowell many other furnaces were built in the Mahoning valley to use the new fuel, and it was also substituted for charcoal in some old furnaces. At a later day the use of this fuel and of Connellsville coke contributed to the further development of the manufacture of pig iron in Ohio, and at a still later and very recent date the opening of the extensive coal beds of the Hocking valley and the utilization of its carbonate ores still further contributed to the same development.

The beginning of the iron industry at Youngstown, which now has within its own limits or in the immediate vicinity twelve furnaces and six rolling mills, dates from about 1835, when a charcoal furnace called Mill Creek was built on a creek of the same name, a short distance southwest of the city, by Isaac Heaton, a son of James Heaton. There was no other furnace at Youngstown until after the discovery at Lowell that the block coal of the Mahoning valley could be successfully used in the smelting of iron ore. In a recent sketch of the history of Youngstown Hon. John M. Edwards says: "In 1846 William Philpot & Co. built in the northwestern part of Youngstown, adjoining the present city, and near the canal, the second furnace in the state for using raw mineral coal as fuel. In the same year a rolling mill was built in the southeastern part of the village, and adjoining the canal, by the Youngstown Iron Company. This mill is now owned by Brown, Bonnell & Co." In a sketch of *Youngstown, Past and Present*, printed in 1875, a fuller account is given of the first bituminous furnace at that place. It was known as the Eagle furnace, and was "built in 1846 by William Philpot, David Morris, Jonathan Warner, and Harvey Sawyer, on land purchased of Dr. Henry Manning, lying between the present city limits and Brier Hill. The coal used was mined from land contiguous, leased from Dr. Manning." The second furnace at Youngstown to use raw coal was built in 1847 by Captain James Wood, of Pittsburgh. It was called Brier Hill furnace.

The proximity of the coal fields of Ohio to the rich iron ores of Lake Superior has been an important element in building up the blast-furnace industry of the state. The use of these ores in Ohio soon followed the first use in the blast furnace of the block coal of the Mahoning valley. An increase in the rolling-mill capacity of Ohio was naturally coincident with the impetus given to the production of pig iron by the use of this coal and Lake Superior ores. David Tod, afterwards governor of Ohio, bore a prominent part in the development of the coal and iron resources of the Mahoning valley.

The iron industry of Cleveland has been built up during this period, and the city is now one of the most prominent centers of iron and steel production in the country. Charles A. Otis, of Cleveland, writes us as follows concerning the first rolling mills in that city: "The first rolling mill at Cleveland was a plate mill, worked on a direct ore process, which was a great failure. It went into operation in 1854 or 1855. The mill is now owned by the Britton Iron and Steel Company. The next mill was built in 1856 by A. J. Smith and others, to reroll rails. It was called Railroad rolling mill, and is now owned by the Cleveland Rolling Mill Company. At the same time a man named Jones, with several associates, built a mill at Newburgh, six miles from Cleveland, also to reroll rails. It was afterwards operated by Stone, Chisholm & Jones, and is now owned by the Cleveland Rolling Mill Company. In 1852 I erected a steam forge to make wrought-iron forgings, and in 1859 I added to it a rolling mill to manufacture merchant bar, etc. The Union rolling mills were built in 1861 and 1862 to roll merchant bar iron."

In the list of persons connected with the development of the iron and steel industries of Cleveland the name of Henry Chisholm is most prominent. Mr. Chisholm was born at Lochgelly, in Fifeshire, Scotland, on April 27, 1822, and died at Cleveland on May 9, 1881, aged 59 years.

From 1846 to 1880 the iron industry of Ohio has made steady progress, and the state now ranks second among the iron-producing states of the Union. This was also its rank in 1870.

EARLY IRON ENTERPRISES IN INDIANA.

Indiana possessed a small charcoal-iron industry before 1850, but at what period in the present century this industry had its beginning cannot now be definitely determined. Tench Coxe makes no reference to it in 1810, but mentions one nailery in the territory, which produced in that year 20,000 pounds of nails, valued at $4,000. He does not locate this enterprise. In 1840 the census mentions a furnace in Jefferson county, one in Parke, one in Vigo, one in Vermillion, and three in Wayne county, the total product being only 810 tons of "cast iron." A forge in Fulton county, producing 20 tons of "bar iron," is also mentioned. The census of 1840, however, frequently confounds furnaces with foundries, and it is therefore possible that some of the alleged furnaces in Indiana at that period were foundries.

In 1859 Lesley enumerated five charcoal furnaces in Indiana, as follows: Elkhart, in Elkhart county, date of erection unknown; La Porte, near the town of that name, in La Porte county, built in 1848; Mishawaka, in Saint Joseph county, built about 1833; Richland, on Richland creek, in Greene county, built in 1844 by A. Downing; and Indiana, a few miles northwest of Terre Haute, in Vigo county, built in 1839. The three last named were in operation in 1857, but were abandoned about 1860. Elkhart and La Porte furnaces were idle in 1857, and probably had been abandoned at that time. Elkhart, La Porte, and Mishawaka used bog ore exclusively, and Richland used it in part; in 1857 Mishawaka was still using it. Indiana furnace used brown hematite found in the neighborhood. In a chapter on the geology of Monroe county, by George K. Greene, printed in 1881, it is stated that "nearly forty years ago an iron furnace was erected by Randall Ross, of Virginia, on the lands of George Adams, of Monroe county, on section 7, township 7, range 2 west. The investment soon proved a failure, and the furnace has long gone to decay. The ruins of the 'old iron furnace' are to-day the mournful monument of an early spirit of enterprise that deserved a better fate." The early Indiana furnaces doubtless made more castings than pig iron.

In 1860 there was only one furnace in blast in Indiana—Richland. It was abandoned probably in that year, and from this time until 1867 no pig iron was made in Indiana. In the latter year the manufacture of pig iron in this state was revived, the development of the block-coal district in the neighborhood of Brazil, in Clay county, having led to the belief that this fuel might be profitably used in blast furnaces. Planet furnace, at Harmony, in Clay county, built in the summer of 1867, and put in blast in November of that year, was the first of eight furnaces that were built in Indiana between 1867 and 1872 to use this coal, the ores for the furnaces being mainly obtained from Missouri and Lake Superior. Five of these furnaces were in Clay county. Of the eight furnaces built, four have been abandoned and torn down since 1872, and, of the remaining four, one is now using charcoal and three are using block coal. No furnaces have been built in Indiana since 1872.

Except the solitary forge above mentioned we have no record of any forges or bloomaries having been built in Indiana at any period. The first rolling mill in the state was probably the Indianapolis mill, built by R. A. Douglas, which was completed in the autumn of 1857, and put in operation in November of the same year. Lesley in 1858 says: "The machinery and building were planned by Lewis Scofield, of Trenton, New Jersey, who also built the Wyandotte mill and is building the mill at Atlanta, Georgia." There were in 1880 nine rolling mills in Indiana, four of which were rail mills. The state contained no steel works in that year.

EARLY IRON ENTERPRISES IN ILLINOIS.

In 1839 a small charcoal furnace was built four miles northwest of Elizabethtown, in Hardin county, in the extreme southeastern part of Illinois, by Leonard White, Chalen Guard & Co. It was called Illinois. This is the first furnace in the state of which there is any record, and it probably had no predecessor. In 1853 it was purchased by C. Wolfe & Co., of Cincinnati, who tore down the stack and built a larger one in 1856, with modern additions. In 1873 this furnace, after having been out of blast for several years, was repaired, but it has not since been put in blast. A charcoal furnace called Martha was built in 1848 by Daniel McCook & Co. about two miles east of Illinois furnace. It was probably the second furnace in the state. Illinois and Martha furnaces were both in blast in 1850, but in 1860 only Illinois was in blast. Martha had not been in operation since 1856, and it probably never made any iron after that year. It has long been abandoned. These furnaces were supplied with limestone ore from the immediate neighborhood. They seem to have been the only charcoal-iron enterprises of any description that ever existed in Illinois.

In the census of 1840 mention is made of a furnace in Cook county, one in Fulton, one in Hardin, and one in Wabash county. The furnaces in Fulton and Hardin counties were idle; the furnace in Wabash county produced eight tons, and the furnace in Cook county produced 150 tons, of "cast iron." As the census of 1840 frequently confounds blast furnaces with foundries, reliance cannot be placed in the correctness of its statements concerning furnaces in Illinois. We have definitely ascertained that there was no furnace in Cook county in that year, and that the furnace with which it is credited in the census was Granger's foundry, the only one in Chicago at that time.

There appears to have been no furnace in operation in Illinois from 1860 to 1868. Soon after the close of the civil war the attention of iron manufacturers was attracted to the Big Muddy coal fields, in the southwestern part of Illinois, and to the proximity to these coal fields of the rich iron ores of Missouri. In 1868 the Grand Tower Mining, Manufacturing, and Transportation Company built two large furnaces at Grand Tower, in Jackson county, Illinois, to use the Big Muddy coal in connection with Missouri ores; and in 1871 another large furnace, called Big Muddy, was built at Grand Tower, by another company, to use the same fuel and ores. The two Grand Tower furnaces have been out of blast for several years and are now abandoned, but the Big Muddy furnace is still in blast. At East Saint Louis the Meier Iron Company built two large coke furnaces between 1873 and 1875. These furnaces are now in operation, their fuel being mainly Carbondale coke, from Jackson county, Illinois.

The iron industry at Chicago and in its vicinity properly dates from 1857, when Captain E. B. Ward, of Detroit, built the Chicago rolling mill, on the right bank of the Chicago river, "just outside of the city." This mill was built to reroll iron rails. It formed the nucleus of the present very extensive works of the North Chicago Rolling Mill Company. There was no furnace at Chicago until 1868, when two furnaces were built by the Chicago Iron Company. They are now owned by the Union Iron and Steel Company. One was blown in early in 1869, and the other late in the same year. Two furnaces were built at Chicago in 1869 by the North Chicago Rolling Mill Company. No other furnaces were built at Chicago until 1880, when seven new furnaces were undertaken, three of which were finished in that year and two in 1881. At Joliet, thirty-seven miles southwest of Chicago, the Joliet Iron and Steel Company built two furnaces in 1873. They are now owned by the Joliet Steel Company.

In 1880 there were thirteen rolling mills and steel works in Illinois, three of which were Bessemer steel works—two at Chicago and one at Joliet, and one was an open-hearth steel works at Springfield. At the beginning of 1880 there were ten blast furnaces in the state, and, as has been mentioned, three new furnaces were finished during the year and four others were undertaken. In 1880 Illinois ranked fourth among the iron and steel producing states of the Union, making a great stride since 1870, when it ranked fifteenth.

EARLY IRON ENTERPRISES IN MICHIGAN.

If we could credit the census of 1840 there were fifteen blast furnaces in Michigan in that year—one in each of the counties of Allegan, Branch, Cass, Kent, Monroe, and Oakland, two in Calhoun, two in Washtenaw, and five in Wayne county. Some of these alleged furnaces were doubtless foundries, particularly in counties lying upon or not very remote from Lake Erie, vessels upon which could bring pig iron for their use from neighboring states. Others were undoubtedly true blast furnaces, producing household and other castings from bog ores. All of the fifteen enterprises mentioned were in the southern part of the state. Their total production in 1840 was only 601 tons of "cast iron." Neither forges nor bloomaries are mentioned in the census of 1840.

From 1840 to 1850 the iron industry of Michigan certainly made no progress, and possibly declined. From 1850 to 1860 a marked improvement took place. Three new furnaces were built in the southern part of the state to use bog ore, and in the northern peninsula and at Detroit and Wyandotte a commencement was made in smelting the rich ores which had been discovered in the now celebrated Lake Superior iron-ore region. In 1859 Lesley enumerated the following bog-ore furnaces in the southern part of the state: Kalamazoo, at the city of that name, in Kalamazoo county, built in 1857 to take the place of an earlier furnace; Quincy, three miles north of the town of that name, in Branch county, built in 1855; and Branch county, one mile from Quincy furnace, built in 1854. All of these bog-ore furnaces made pig iron in 1857. It is a curious fact that furnaces to use bog ore should have been built in this country after 1850.

The development of the Lake Superior iron-ore region marks an important era in the history of the American iron trade, and the incidents attending its commencement have fortunately been preserved.

We learn from A. P. Swineford's *History of the Lake Superior Iron District* that the existence of iron ore on the southern border of Lake Superior was known to white traders with the Indians as early as 1830. The same writer further informs us that the first discovery by white men of the iron ore of this region was made by William A. Burt, a deputy surveyor of the General Government, on the 16th of September, 1844, near the eastern end of Teal lake. In June, 1845, the Jackson Mining Company was organized at Jackson, Michigan, for the purpose of exploring the mineral districts of the southern shore of Lake Superior, and in the summer of the same year this company, through the disclosures of a half-breed Indian, named Louis Nolan, and the direct agency of an old Indian chief, named Man-je-ki-jik, secured possession of the now celebrated Jackson iron mountain, near the scene of Mr. Burt's discovery. It appears, however, that the representatives of the company had not heard of Mr. Burt's discovery until they met Nolan and the Indian chief. Mr. P. M. Everett, the president of the company, was the leading spirit of the exploring party which secured possession of this valuable property. The actual discovery of Jackson mountain was made by S. T. Carr and E. S. Rockwell, members of Mr. Everett's party, who were guided to the locality by the Indian chief.

In a letter written on the 10th of November, 1845, at Jackson, Michigan, Mr. Everett, referring to the ore of Jackson mountain, says that "since coming home we have had some of it smelted, and find that it produces iron and something resembling gold—some say it is gold and copper." This smelting is not further described. In 1846 A. V. Berry, one of the Jackson Mining Company, and others, brought about 300 pounds of the ore to Jackson, and in August of that year, writes Mr. Berry, "Mr. Olds, of Cucush Prairie, who owned a forge, then undergoing repair, in which he was making iron from bog ore, succeeded in making a fine bar of iron from our ore in a blacksmith's fire—the first iron ever made from Lake Superior ore." Mr. Swineford says that "one end of this bar of iron Mr. Everett had drawn out into a knife-blade."

In 1847 the Jackson Mining Company commenced the erection of a forge on Carp river, about ten miles from its mouth, and near Jackson mountain, which was finished early in 1848, and on the 10th of February of that year the first iron made in the Lake Superior region was made at this forge by Ariel N. Barney. Mr. Swineford says that the forge, which was named after Carp river, had "eight fires, from each of which a lump was taken every six hours, placed under the hammer, and forged into blooms four inches square and two feet long, the daily product being about three tons. The first lot of blooms made at this forge—the first iron made on Lake Superior, and the first from Lake Superior ores, except the small bar made by Mr. Olds—was sold to the late E. B. Ward, and from it was made the walking-beam of the side-wheel steamer *Ocean*." The forge was kept in operation until 1854, when it was abandoned, having in the mean time "made little iron and no money."

In 1849 the Marquette Iron Company, a Worcester (Massachusetts) organization, undertook the erection of a forge at Marquette, and in July, 1850, it was finished and put in operation. Mr. Swineford says that "it started with four fires, using ores from what are now the Cleveland and Lake Superior mines." It was operated irregularly until December, 1853, when it was burned down and was not rebuilt.

The Collins Iron Company was organized in 1853, with Edward K. Collins, of New York, at its head, and in 1854 it built a forge on Dead river, about three miles northwest of Marquette, and in the fall of 1855 the manufacture of blooms was commenced from ore obtained at the company's mines. This forge was in operation in 1858, after which time it seems to have been abandoned.

Another forge on Dead river was built in 1854 or 1855 by William G. McComber, Matthew McConnell, and J. G. Butler. The company failed in a few years, and in 1860 Stephen R. Gay erected Bancroft furnace on the site of the forge. Before 1860 every forge in Michigan appears to have been abandoned.

It will be observed that all of the first iron enterprises in the Lake Superior district were bloomary forges, the intention evidently having been to build up an iron industry similar to that of the Lake Champlain district.

The first pig iron produced in the Lake Superior region was made in 1858 by Stephen R. Gay, who then leased the forge of the Collins Iron Company and converted it in two days, at an expense of $50, into a miniature blast furnace. Mr. Gay writes to C. A. Trowbridge that this furnace was "2½ feet across the bosh, 8 feet high, and 12 inches square at the top and 15 inches square in the hearth," and would hold eight bushels of coal. He gives the following details of its first and only blast: "Began on Monday, finished and fired on Wednesday, filled with coal Thursday noon, blast turned on Friday noon, and thenceforth charged regularly with 1 bushel coal, 20 pounds of ore, and 7 pounds of limestone. Cast at six o'clock 500 pounds, and again at eight o'clock Saturday morning, half a ton in all, 92 pounds of which were forged by Mr. Eddy into an 85-pound bloom. This little furnace was run two and a half days, made 2½ tons, carrying the last eight hours 30 pounds of ore to a bushel of coal, equal to a ton of pig iron to 100 bushels of coal." These experiments were made in February.

The first regular blast furnace in the Lake Superior region was built by the Pioneer Iron Company in the present city of Negaunee, convenient to the Jackson mine. It was commenced in June, 1857, and in February, 1858, it was finished. Another stack was added in the same year. These furnaces took the name of the company. Pioneer No. 1 was put in blast in April, 1858, and Pioneer No. 2 on May 20, 1859. Both furnaces are now owned by the Iron Cliffs Company, and both were in operation in 1880. The second regular blast furnace in this region was the Collins furnace, built in 1858 by Stephen R. Gay, near the site of the Collins forge. It made its first iron on December 13 of that year. It was abandoned in 1873, owing to the failure of a supply of charcoal. Other furnaces in the Lake Superior region soon followed the erection of the Pioneer and Collins furnaces.

While these early furnaces and the few forges that have been mentioned were being built on the shore of Lake Superior two furnaces were built at or near Detroit to smelt Lake Superior ores. These were the Eureka furnace, at Wyandotte, built in 1855 by the Eureka Iron Company, of which Captain E. B. Ward was president, and put in blast in 1856; and the Detroit furnace, at Detroit, built in 1856 by the Detroit and Lake Superior Iron Manufacturing Company, of which George B. Russell was president, and put in blast in January, 1857. These furnaces and the others that have been mentioned used charcoal as fuel.

The first shipment of iron ore from the Lake Superior region was made in 1850, according to Mr. Swineford, and consisted of about five tons, "which was taken away by Mr. A. L. Crawford, of Newcastle, Pennsylvania." A part of this ore was made into blooms and rolled into bar iron. "The iron was found to be most excellent, and served to attract the attention of Pennsylvania ironmasters to this new field of supply for their furnaces and rolling mills." In 1853 three or four tons of Jackson ore were shipped to the World's Fair at New York.

The first use of Lake Superior ore in a blast furnace occurred in Pennsylvania. The important event is described in a letter to us from David Agnew, of Sharpsville, Mercer county, Pennsylvania, from which we quote as follows:

> The Sharon Iron Company, of Mercer county, Pennsylvania, about the year 1850 or 1851 purchased the Jackson mines, and, in expectation of the speedy completion of the Sault canal, commenced to open them, to construct a road to the lake, and to build docks at Marquette, expending a large sum of money in these operations. The opening of the canal was, however, unexpectedly delayed until June, 1855. Anxious to test the working qualities of this ore, the Sharon Iron Company brought, at great expense, to Erie, in the year 1853, about 70 tons of it, which was shipped by canal to Sharpsville furnace, near Sharon, owned by David and John P. Agnew. The first boat-load of ore, on its receipt, was immediately used in the furnace, partly alone and partly in mixture with native ores, and the experiment was highly successful, the furnace working well and producing an increased yield of metal, which was taken to the Sharon iron works and there converted into bar iron, nails, etc., of very superior quality. The second boat-load of ore was also brought to Sharpsville, but, having been intended to be left at the Clay furnace, owned by the Sharon Iron Company, was returned and used at that establishment.

In 1854, 1855, and 1856 Clay furnace continued the use of Lake Superior ore, most of it mixed with native ore, and used in all until August, 1856, about 400 tons. "Up to that date," as is stated by Mr. Frank Allen, its manager, "the working of it was not a success. In October, 1856, we gave the Clay furnace a general overhauling, put in a new lining and hearth, and made material changes in the construction of the same, put her in blast late in the fall, and in a few days were making a beautiful article of iron from Lake Superior ore alone." The fuel used at Sharpsville and Clay furnaces was the block coal of the Shenango valley. After 1856 other furnaces in Pennsylvania and in other states began the regular use of Lake Superior ore.

Until about 1877 the mining of iron ore in the Lake Superior region was confined to the territory in the immediate vicinity of Marquette. Since 1877, and particularly since 1879, a new iron-mining region has been developed in the northern part of Menominee county and the southern part of Marquette county, which takes its name from the former county. This region has proved to be very productive and the ore to be very desirable.

Since the discovery of iron ore in the Lake Superior region there have been built on the upper peninsula, in the vicinity of the mines, twenty-three furnaces, of which ten have been abandoned. There have also been built at other points in the state of Michigan, to use Lake Superior ore, fifteen furnaces, of which none had been abandoned in 1880. All of these furnaces, with the exception of two at Marquette, were built to use charcoal, and the abandonment of many of them in the upper peninsula is attributable to the scarcity of timber for fuel. Michigan is, however, the first state in the Union to-day in the manufacture of charcoal pig iron, having twenty-eight furnaces, of which all but one furnace at Marquette now use charcoal when in operation. The three bog-ore furnaces in Kalamazoo and Branch counties have been abandoned.

There are now two active rolling mills in Michigan—the Eureka, formerly the Wyandotte, at Wyandotte, built in 1855, and the rolling mill of the Baugh Steam Forge Company, at Detroit, built in 1877, the forge having been built in 1870. In 1871 a rolling mill was built at Marquette, which has since been abandoned. In 1872 a rolling mill was built at Jackson, in Jackson county, but it was torn down in 1879, and the machinery removed to the mill of the Springfield Iron Company at Springfield, Illinois.

From the Marquette *Mining Journal*, edited by Mr. Swineford, we take the following statement in gross tons of the aggregate production of the Lake Superior iron-ore mines for each calendar year since the commencement of mining operations in the district.

Year.	Gross tons.	Year.	Gross tons.	Year.	Gross tons.	Year.	Gross tons.
1856 and previous	86,319	1863	203,055	1870	859,507	1877	1,025,129
1857	25,646	1864	247,059	1871	813,984	1878	1,125,093
1858	22,876	1865	193,758	1872	948,553	1879	1,414,182
1859	68,832	1866	296,713	1873	1,195,234	1880	1,987,598
1860	114,401	1867	465,504	1874	935,488	Total	15,321,128
1861	114,258	1868	510,522	1875	910,840		
1862	124,169	1869	639,097	1876	993,311		

The iron ores of Lake Superior that are not used in Michigan are mainly shipped to Ohio, Pennsylvania, Illinois, and Wisconsin. About one-third of all the pig iron that is now manufactured in the United States is made from these ores.

Captain Ward was the most prominent of all the iron manufacturers of Michigan, his enterprise in this respect extending to other states than his own. He was born in Canada, of Vermont parents, on December 25, 1811, and died suddenly at Detroit, on January 2, 1875.

In 1870 Michigan ranked eighth in the list of iron-producing states, and in 1880 its rank was the same.

THE EARLY MANUFACTURE OF IRON IN WISCONSIN.

In 1840 the census mentions a furnace in "Milwaukee town," which produced three tons of iron in that year. This was doubtless a small foundry. In 1859 Lesley mentions three charcoal furnaces in Wisconsin—Northwestern, or Mayville, at Mayville, in Dodge county, forty miles northwest of Milwaukee, and five miles from the Iron ridge, built in 1853 by the owners of Mishawaka furnace in Indiana, and to which a foundry was added in 1858; Ironton, at Ironton, in Sauk county, built in 1857 by Jonas Tower; and Black River, built in 1857 by a German company on the east bank of Black river, near the falls, in German county. Of these furnaces at least one, Ironton, was built to produce castings. A description of it in 1858 says: "It is a small blast furnace capable of producing about three tons of iron per day, and intended for the manufacture of stoves, castings, etc." The Ironton furnace still produces castings as well as pig iron. The Mayville furnace is also still in operation, having been rebuilt in 1872, but the Black River furnace has long been abandoned. There appear to have been no forges or bloomaries in Wisconsin in 1840, 1850, or 1860.

The furnaces which have been mentioned were all that the state could boast until 1865, when a charcoal furnace at Iron Ridge, in Dodge county, was built by the Wisconsin Iron Company. This was soon followed by several other furnaces, some of which were built to use native ores and some to use Michigan ores from Lake Superior. The Appleton Iron Company built two furnaces at Appleton, in Outagamie county, in 1871 and 1872; C. J. L. Meyer built a furnace at Fond du Lac in 1874, but it had not been put in blast down to November 15, 1881; the Fox River Iron Company built two furnaces at West Depere, in Brown county, in 1869 and 1872; the Green Bay Iron Company built a furnace at Green Bay, in the same county, in 1870; and the National Furnace Company built two furnaces at Depere, in the same county, in 1869 and 1872. All of these furnaces were built to use charcoal. In 1870 and 1871 the Milwaukee Iron Company built two large furnaces at Bay View, near Milwaukee, and in 1873 the Minerva Iron Company built a furnace at Milwaukee. These three furnaces were built to use mineral fuel and Lake Superior ores. A furnace called Richland was built in 1876 at Cazenovia, in Richland county, and was torn down in 1879. In 1880 there were fourteen furnaces in the state, eleven of which used charcoal and three used anthracite coal and coke.

Wisconsin had no rolling mill until 1868, when its first and thus far its only mill was built at Milwaukee by the Milwaukee Iron Company, of which Captain E. B. Ward was a leading member. This was from the first a large mill, and was built to roll new iron rails. In 1874 a merchant bar mill was added. This mill and the two Bay View furnaces are now operated by the North Chicago Rolling Mill Company.

Wisconsin advanced rapidly in the manufacture of iron in the decade between 1870 and 1880, and in the latter year it ranked sixth among the iron-producing states of the Union. In 1870 it was twelfth in rank.

EARLY IRON ENTERPRISES IN MISSOURI.

Missouri has an iron history which antedates its admission into the Union in 1820. The celebrated iron district, in Iron and Saint Francois counties, which embraces Iron Mountain and Pilot Knob, contained a blast furnace before 1819, and possibly as early as 1812 or 1814, as we find in a prospectus of the Missouri Iron Company, written in 1837, the statement that "cannon balls, made from the Iron Mountain ore during the late war, after having been exposed for several years to the open atmosphere and rains, still maintained their original metallic lustre." The cannon balls referred to would probably be used for the defense of New Orleans. This furnace was called Springfield, and was situated in the vicinity of Iron Mountain, and about forty miles from the Mississippi river, but its exact location we cannot learn. It was in Washington county, as the county was then bounded. In 1858 Lesley says that "an old charcoal furnace was once in operation in township 33, range 4 north, half section 2" of Iron county. This may have been Springfield furnace. John Perry and Colonel Ruggles, whether jointly or severally the authority from which we quote does not state, operated Springfield furnace "for more than fifteen years" prior to 1837. In that year the furnace was in operation, when it was called "a small furnace." A forge was then attached to it, and "a blooming forge" was promised "the ensuing year."

Maramec furnace, in Phelps county, about sixty miles west of Iron Mountain, was built in 1826, and rebuilt many years afterwards. It is still standing but not in operation. At an early day a forge was added to the furnace, to convert its pig iron into bar iron, and this forge, with eight fires, is also still standing but not in operation, its product when last employed being charcoal blooms. In 1843 a rolling mill was added, but it was "abandoned after one year's trial, because of the sulphur in the stone coal obtained at a bank fourteen miles southeast."

In the census of 1840 Missouri is credited with two furnaces—one in Crawford county, and one in Washington county. It is also credited with three forges in Crawford county and one in Washington county. The furnace in Crawford county was Maramec—Phelps county not having been then organized, and the forges in Crawford county were probably attached to Maramec furnace. The furnace in Washington county was Springfield, and the forge was doubtless the one attached to this furnace. We do not hear of Springfield furnace and forge after this time.

In 1836 the remarkable iron-ore mountains already mentioned—Iron Mountain and Pilot Knob—attracted the attention of some Missouri capitalists, and in the fall of that year the Missouri Iron Company, with a nominal capital of $5,000,000, was formed to utilize their ores, the legislature chartering the company on December 31, 1836. In January, 1837, the company was fully organized under the presidency of Silas Drake, of Saint Louis, who was soon succeeded by J. L. Van Doren, of Arcadia, but active work in the development of its property does not appear to have been undertaken until some years afterwards, when a few furnaces were erected at the foot of the mountains by other companies. In 1846 a furnace was built at the southwest base of Little Iron Mountain, which was followed in 1850 by another furnace at the same place, and in 1854 by still another. In 1849 a furnace was built on the north side of Pilot Knob, which was followed in 1855 by another at the same place. These were all charcoal furnaces, and were exceptionally well managed in 1857, when they were visited and described by Charles B. Forney, of Lebanon, Pennsylvania. At that time two of the Iron Mountain furnaces and one of the Pilot Knob furnaces were blown with hot-blast.

In 1846 Moselle furnace was built at Moselle, in Franklin county, and in 1859 a furnace was built at Irondale, in Washington county—both furnaces to use charcoal. These, with the furnaces previously mentioned, appear to be all that were built in Missouri prior to 1860. It will be observed that they were all built in the same part of the state—southwest of Saint Louis.

The iron industry of Saint Louis appears to have had its commencement in 1850, when the Saint Louis, or Laclede, rolling mill was built. It was followed by the Missouri rolling mill, built in 1854; by the Allen rolling mill, built in 1855; by the Pacific rolling mill, built in 1856; and by Raynor's rolling mill, built in 1858. In 1880 there were seven rolling mills in Saint Louis, and there were no others in Missouri. One of these mills, the Vulcan, built in 1872, was connected with the Bessemer steel works of the Vulcan Steel Company, and rolled steel rails. Two other mills rolled light rails and bar iron. The Bessemer works of the Vulcan Steel Company were built in 1875 and 1876. The state had no other steel works in 1880.

Saint Louis had no blast furnaces until 1863, when the Pioneer furnace was built at Carondelet, to use coke. It was in blast in 1873, but in 1874 it was torn down and removed by the Pilot Knob Iron Company. In 1869 the Vulcan Iron Works, now called the Vulcan Steel Company, built two furnaces, which were followed in 1872 by another furnace built by the same company. In 1870 and 1872 the South Saint Louis Iron Company built two furnaces; in 1870 the Missouri Furnace Company built two; and in 1873 Jupiter furnace was built, but it was not put in blast until 1880. These eight furnaces were all built to use Illinois or Connellsville coke and Missouri ores.

In 1871 a large forge was built at South Saint Louis, called the Germania iron works, to make charcoal blooms from pig iron, but it has been idle for several years. In 1873 a forge was built at Kimmswick, in Jefferson county, and enlarged and remodeled in 1877 by the Peckham Iron Company, its product after the enlargement being charcoal blooms from the ore. It was in operation in 1880.

There were in 1880 ten charcoal furnaces and eight coke furnaces in Missouri, and two charcoal furnaces were in course of erection. During the decade between 1870 and 1880 the iron industry of Missouri was subject to exceptional vicissitudes, but in the latter year it was apparently placed upon a more substantial basis of prosperity than it had ever before occupied, and to-day its future is hopeful, although it has lost the prominent rank it held among iron-producing states in 1870. It then ranked sixth, but in 1880 it had fallen to the tenth place. The shipments of iron ore from Missouri to other states have for many years averaged over 100,000 tons annually.

THE MANUFACTURE OF IRON IN VARIOUS WESTERN STATES AND IN THE TERRITORIES.

Minnesota has one furnace, situated at Duluth, which was commenced in 1873 and not finished until 1880, when it was put in blast. Its projectors failed, and after passing through the hands of creditors it was purchased by the Duluth Iron Company, its present owners. It uses charcoal as fuel and obtains its supply of ore from the Lake Superior mines in Michigan.

In 1857 a bloomary called Big Creek was built about six miles southwest of Smithville, in Lawrence county, Arkansas, by Alfred Bevens & Co. In 1858 Lesley describes it as "a bloomary with two fires and a hammer, making 250 pounds of swedged iron per day per fire, with a cold-blast in November, 1857, but has now a hot-blast, and is making perhaps 800 pounds, using 300 bushels of charcoal to the ton of finished bars, made out of brown hematite ore." The bloomary was driven by water-power. It is not mentioned in the census of 1860 or 1870, and has been abandoned. We have no knowledge of any other iron-manufacturing enterprise having ever existed in this state.

Texas does not appear to have had any iron enterprises of any kind before the civil war, but three small furnaces are reported to have been abandoned at the close of the war. They were probably built during its continuance to meet the necessities of the Confederate government. In 1869 a charcoal furnace was built at Jefferson, in Marion county, which was rebuilt in 1874. It was in operation in 1880, and was then the only furnace in the state. It is called Kelly furnace, after Mr. G. A. Kelly, the president of the Jefferson Iron Company, by which it is owned. It uses brown hematite ore found in the neighborhood.

Kansas had two rolling mills in operation in 1880, both of which were built to reroll rails. One of these, at Rosedale, in Wyandotte county, three miles from Kansas City, is owned by the Kansas Rolling Mill Company. This mill was once in operation at Decatur, Illinois, where it was built in 1870, and whence it was removed to Rosedale in 1875. The other mill is located at Topeka, and was built in 1874 by the Topeka Rolling Mill Company. This mill was burned in April, 1881.

Nebraska had one iron enterprise in operation in 1880—a rolling mill and cut-nail factory at Omaha, owned by the Omaha Iron and Nail Company. These works were first built at Dunleith, Illinois, in 1875 and 1876, and were removed to Omaha in 1879 and considerably enlarged. They have a capacity of 60,000 kegs of nails annually. They use old iron exclusively.

In 1877 a rolling mill was removed by William Faux from Danville, Pennsylvania, to Pueblo, Colorado, and put in operation on March 1, 1878, its product being rerolled rails. In the same year it was removed to Denver. It was in operation in 1880, rolling bar iron as well as rerolling rails. This mill is now owned by the Colorado Coal and Iron Company. In 1880 this company commenced the erection of a large coke furnace at South Pueblo, in Colorado, which was put in blast on September 7, 1881. In the former year it commenced the construction of Bessemer steel works at the same place. These enterprises are the pioneers of a very extensive and complete iron and steel establishment which has been projected by this company, and which is to embrace two blast furnaces, Bessemer steel works, and a rolling mill for rolling steel rails. Coke works on an extensive scale have already been built by the company at El Moro. The number of ovens now completed is over 200, and others are being erected. Colorado has apparently a great future before it in the production of iron and steel, all the elements necessary to their manufacture being found within its limits.

The Union Pacific Railroad Company built a rolling mill to reroll rails at Laramie City, Wyoming territory, in 1874, and put it in operation in April, 1875. It was in operation in 1880.

In 1859 Lesley reported a forge in Utah territory, "smelting iron ore found in the mountains east of Salt Lake City, but no reliable information could be obtained respecting it." It does not appear in the census of 1860. Dr. J. S. Newberry writes that in 1880 he "visited the deposit of crystalline iron ore of Iron county, in the southern part of the territory. These ore beds have been long known, and were to some extent utilized by the Mormons in their first advent thirty years ago. The iron region referred to lies nearly 300 miles directly south of Salt Lake City." In 1874 the Great Western Iron Company, of which John W. Young was president, built a charcoal furnace at Iron City, in Iron county. It was in blast in that year and in the two following years, but has since been idle.

This is a very small furnace, being only nineteen feet high and four feet wide at the boshes, with a daily capacity of five tons. The erection of a much larger furnace, also to use charcoal, was commenced at Ogden City, Utah, in 1875, by the Ogden Iron Manufacturing Company, and was intended to use hematite and magnetic ores found in the neighborhood. The furnace had not been put in blast at the close of 1880, and was not then entirely completed. The same company commenced to build a rolling mill at Ogden City in 1875, which had not been completed in 1880.

California has for many years had a very complete rolling mill at San Francisco, owned by the Pacific Rolling Mill Company. It was first put in operation on July 25, 1868. It rolls rails, bar iron, angle iron, shafting, etc. It was in operation in 1880, and has always been well employed. The California Iron Company commenced in 1880 the erection of a charcoal furnace at Clipper Gap, in Placer county, where iron ore had been discovered, and in the same year the Central Pacific Railroad Company commenced the erection at Sacramento City of a small mill to roll bar iron. The Clipper Gap furnace was successfully put in blast in April, 1881, and the first cast was made on the 24th of that month. California may have had a forge or two while it was Mexican territory, but it is doubtful whether its Mexican inhabitants ever engaged in the manufacture of iron.

At Oswego, in Clackamas county, Oregon, a furnace to use charcoal was built in 1866 and enlarged in 1879. It was in blast in 1880, when it produced 5,000 net tons of pig iron. Its charcoal is made exclusively from the fir tree.

A furnace at Irondale, near Port Townsend, in Jefferson county, Washington territory, was built in 1880, and put in blast early in 1881. It is a small furnace, and was built to make charcoal pig iron from Puget sound bog ore mixed with Texada Island magnetic ore. It is owned by the Puget Sound Iron Company, of Port Townsend. The company is said to contemplate the erection of another blast furnace on Texada Island, which is in British Columbia.

THE FIRST IRON WORKS IN CANADA.

A brief notice in this report of the first iron works in Canada seems to be proper, more especially as these works are still in operation. They are known as the Forges of the St. Maurice, and are located near Three Rivers, in the province of Quebec. Mr. A. T. Freed, one of the editors of the Hamilton (Ontario) *Spectator*, informs us that iron ore in the vicinity of Three Rivers was discovered as early as 1666. In 1685 the Marquis de Denouville sent to France a sample of the ore at Three Rivers, which the French ironworkers found to be "of good quality and percentage." In 1672 the Count de Frontenac reported that he had begun to mine the ore at Three Rivers. He strongly urged the establishment of forges and a foundry. But no effort to establish iron works at this place appears to have been made until the next century, when the St. Maurice works were undertaken. Dr. T. Sterry Hunt, of Montreal, has supplied us with the following brief history of these works.

King Louis XIV. gave a royal license in 1730 to a company to work the iron ores of St. Maurice and the vicinity, and advanced 10,000 livres for aid in erecting the furnace, etc. No work being done he took back the license, and in 1735 granted it to a new company, which received 100,000 livres in aid, and in 1737 built a blast furnace. In 1843, however, the works reverted to the crown, and were worked for the king's profit. He then sent out from France skilled workmen, who rebuilt, in part at least, the blast furnace as it now stands, and erected a Walloon hearth, which is still in use, for refining. The works became the property of the British Crown at the conquest, and were at first rented to a company and afterwards sold. Smelting has been carried on at this place without interruption to the present time, the bog ores of the region being exclusively used. Three tons of ore make one ton of iron.

There seems to be no doubt that the stack is the one built in 1737, and it is still in blast. It is 30 feet high, and the internal diameter at the hearth is 2½ feet, at the boshes 7 feet, and at the throat 3½ feet. There are two tuyeres, and the blast is cold, with a pressure of one pound. The daily production of iron is four tons, and the consumption of charcoal is 180 bushels, (French,) of about 12 pounds each, per ton of iron. The metal was formerly used in the district for ordinary castings, but is now in great demand for car wheels. A very little is, however, refined in the Walloon hearth, and is esteemed by the blacksmiths for local use. The analysis of a sample of the gray pig of St. Maurice made by me in 1868 gave: Phosphorus, .450; silicon, .860; manganese, 1.240; graphite, 2.820; carbon combined, 1.100.

In addition to the above information from Dr. Hunt, we find some facts of interest concerning the St. Maurice iron works in Peter Kalm's *Travels into North America*, written in 1749.

The iron work, which is the only one in this country, lies three miles to the west of Trois Rivieres. Here are two great forges, besides two lesser ones to each of the great ones, and under the same roof with them. The bellows were made of wood, and everything else as it is in Swedish forges. The melting ovens stand close to the forges, and are the same as ours. The ore is got two French miles and a half from the iron works, and is carried thither on sledges. It is a kind of moor ore, which lies in veins, within six inches or a foot from the surface of the ground. Each vein is from six to eighteen inches deep, and below it is a white sand. The veins are surrounded with this sand on both sides, and covered at the top with a thin mould. The ore is pretty rich and lies in loose lumps in the veins, of the size of two fists, though there are a few which are eighteen inches thick. These lumps are full of holes, which are filled with ochre. The ore is so soft that it may be crushed betwixt the fingers. They make use of a grey limestone, which is broke in the neighborhood, for promoting the fusibility of the ore; to that purpose they likewise employ a clay marble, which is found near this place. Charcoals are to be had in great abundance here, because all the country round this place is covered with woods which have never been stirred. The charcoals from evergreen trees, that is from the fir kind, are best for the forge, but those of deciduous trees are best for the smelting oven. The iron which is here made was to me described as soft, pliable, and tough, and is said to have the quality of not being attacked by rust so easily as other iron; and in this point there appears a great difference between the Spanish iron and this in shipbuilding.

This iron work was first founded in 1737, by private persons, who afterwards ceded it to the king; they cast cannon and mortars here, of different sizes, iron stoves, which are in use all over Canada, kettles, etc., not to mention the bars which are made here. They have likewise tried to make steel here, but cannot bring it to any great perfection, because they are unacquainted with the manner of preparing it.

Mr. Freed says that the French company which established the St. Maurice iron works in 1737 was known as *Cugnet et Cie.* He also says that there was a French garrison at Trois Rivieres at the time, and that the soldiers were the principal workmen. He sends us a copy of a report made in 1752 to M. Bigot, Intendant of New France, residing at Quebec, by M. Franquet, who had been instructed to visit and examine the St. Maurice works. From this report the following extract is taken:

On entering the smelting forge I was received with a customary ceremony: the workmen moulded a pig of iron about 15 feet long for my especial benefit. The process is very simple: it is done by plunging a large ladle into the liquid-boiling ore and emptying the material into a gutter made in the sand. After this ceremony I was shown the process of stove moulding, which is also a very simple but rather intricate operation. Each stove is in six pieces, which are separately moulded; they are fitted into each other and form a stove about three feet high. I then visited a shed where the workmen were moulding pots, kettles, and other hollow-ware. On leaving this part of the forge we were taken to the hammer forge, where bar iron of every kind is hammered out. In each department of the forges the workmen observed the old ceremony of brushing a stranger's boots, and in return they expect some money to buy liquor to drink the visitor's health. The establishment is very extensive, employing upward of 180 men. Nothing is consumed in the furnaces but charcoal, which is made in the immediate vicinity of the post. The ore is rich, good, and tolerably clean. Formerly it was found on the spot; now the director has to send some little distance for it. This iron is preferred to the Spanish iron, and is sold off in the king's stores in Quebec.

Still quoting from Mr. Freed, we learn that in 1815 a visitor to the St. Maurice works wrote as follows: "The foundry itself is replete with convenience for carrying on an extensive concern; furnaces, forges, casting-houses, workshops, etc. The articles manufactured consist of stoves of all descriptions that are used throughout the provinces, large caldrons or kettles that are used for making potashes, machinery for mills, with cast or wrought iron-work of all denominations. There are likewise large quantities of pig and bar iron exported. The number of men employed is from 250 to 300." The works remained in the ownership of the British government until 1846, when they were sold to Henry Stuart. The latest information concerning them is contained in a report to the Dominion Parliament in 1879, which says that they were then owned by F. Macdougall & Son, of Three Rivers, and were using bog ore and making good iron with charcoal. "The first furnace was erected in 1737; still running; capacity four tons."

THE MANUFACTURE OF IRON IN THE UNITED STATES WITH ANTHRACITE COAL.

The details which have been given in preceding chapters of the early iron history of the Atlantic states of the Union relate almost entirely to the manufacture of charcoal iron, no other fuel than charcoal having been used in American blast furnaces until about 1840. The period of our iron history prior to 1840 may therefore very properly be styled the charcoal era. The later development of the iron and steel industries of the Atlantic states and of other states which have a more modern iron history will be generally instead of provincially treated in the present and succeeding chapters.

The line which separates the charcoal era of our iron history from the era which succeeded it, and which may be said to still continue, is marked by the introduction of anthracite and bituminous coal in the manufacture of pig iron. This innovation at once created a revolution in the whole iron industry of the country. Facilities for the manufacture of iron were increased; districts which had been virtually closed to the manufacture because of a local scarcity of charcoal were now opened to it; and the cheapening of prices, which was made possible by the increased production and consequent increased competition, served to stimulate consumption. A notable effect of the introduction of mineral fuel was that, while it seriously affected the production of charcoal pig iron in states which, like Pennsylvania, possessed the new fuel, it did not injuriously affect the production of charcoal pig iron in other states. Some of these states, like Michigan, which scarcely possessed an iron industry of any kind in 1840, now manufacture large quantities of charcoal pig iron. The country at large now annually makes more charcoal pig iron than it did in 1840 or in any preceding year. The introduction of mineral fuel did not, therefore, destroy our charcoal-iron industry, but simply added to our resources for the production of iron. This introduction, however, marked such radical changes in our iron industry, and so extended the theater of this industry, that we are amply justified in referring to it as a revolution, and as one which ended the distinctive charcoal era.

Of the two forms of mineral fuel—anthracite and bituminous coal—anthracite was the first to be largely used in American blast furnaces, and for many years after its adaptability to the smelting of iron ore was established it was in greater demand for this purpose than bituminous coal. In recent years the relative popularity of these two fuels for blast-furnace use has been reversed.

The natural difficulties in the way of the successful introduction of anthracite coal in our blast furnaces were enhanced by the fact that, up to the time when we commenced our experiments in its use, no other country had succeeded in using it as a furnace fuel. The successive steps by which we were enabled to add the manufacture of anthracite pig iron to that of charcoal pig iron will be presented in chronological order.

In 1840 Jesse B. Quinby testified, in the suit of Farr & Kunzi against the Schuylkill Navigation Company, that in 1815 he used anthracite coal for a short time at Harford furnace, Maryland, mixed with one-half charcoal.

Between 1824 and 1828 Peter Ritner, whose brother, Joseph Ritner, afterwards became governor of Pennsylvania, was successful for a short time in using anthracite coal in a charcoal furnace in Perry county, Pennsylvania, mixed with charcoal. In 1826 the Lehigh Coal and Navigation Company erected near Mauch Chunk, in Pennsylvania, a small furnace intended to use anthracite coal in smelting iron ore. The enterprise was not successful. In 1827 unsuccessful experiments in smelting iron ore with anthracite coal from Rhode Island were made at one of the small blast furnaces in Kingston, Plymouth county, Massachusetts. In 1827 and 1828 a similar failure in the use of anthracite coal took place at Vizille, in France. All of these experiments failed because the blast used was cold. The hot-blast had not then been invented.

In 1828 James B. Neilson, of Scotland, obtained a patent for the use of hot air in the smelting of iron ore in blast furnaces, and in 1829 pig iron was made in several Scotch furnaces with the apparatus which he had invented. But the coal used was bituminous. It was not until 1836 that the smelting of iron ore with anthracite coal by means of the hot-blast invented by Neilson was undertaken in Great Britain. In the mean time the application of the hot-blast to anthracite coal in American furnaces was successfully experimented upon by an enterprising German-American, the Rev. Dr. Frederick W. Geissenhainer, a Lutheran clergyman of New York city. A copy in his own handwriting of a letter written by him in November, 1837, to the commissioner of patents, gives some interesting and valuable details concerning his experiments. In this letter, which we have before us, he says: "I can prove that, in the month of December, 1830, and in the months of January, February, and March, 1831, I had already invented and made many successful experiments as well with *hot air* as with an atmospheric air blast to smelt iron ore with anthracite coal in my small experimenting furnace here in the city of New York."

On the 5th of September, 1831, Dr. Geissenhainer filed in the patent office at Washington an account of his invention, for which he claimed a patent. On the 19th of December, 1833, a patent was granted to him for "a new and useful improvement in the manufacture of iron and steel by the application of anthracite coal." From the long and remarkably clear and learned specification by the Doctor, which accompanied the patent, we learn that he discovered that iron ore could be smelted with anthracite coal by applying "a blast, or a column, or a stream or current of air in or of such quantity, velocity, and density or compression as the compactness or density and the continuity of the anthracite coal requires. The blast may be of common atmospheric *or of heated air*. Heated air I should prefer in an economical point of view."

The Doctor distinctly disclaims in his specification "an exclusive right of the use of heated air for any kind of fuel," from which it is to be inferred that he had full knowledge of Neilson's experiments with hot air in Scotland. He appears to have relied for success largely upon the effect of a strong blast.

The patent having been granted, Dr. Geissenhainer proceeded to build a furnace for the practical application of his invention. This was Valley furnace, situated on Silver creek, in Schuylkill county, Pennsylvania, about ten miles northeast of Pottsville. In August and September, 1836, he was successful in making pig iron at this furnace exclusively with anthracite coal as fuel. His own testimony on this point is given in the letter from which we have already quoted. The blast used varied from $3\frac{1}{2}$ to $3\frac{1}{4}$, to 3, and to $2\frac{3}{4}$ pounds to the square inch. That the furnace did not continue to make iron after the fall of 1836 is explained by Dr. Geissenhainer to have been due to an accident to its machinery. He adds: "My furnace would have been put in operation again long before this time with strong iron machinery, and a hot-air apparatus, had I not been prevented by the pressure of the times and by a protracted severe sickness from bestowing my attention to this matter. The drawings for the iron machinery and for the hot-air apparatus are already in the hands of Messrs. Haywood & Snyder, in Pottsville, who are to do the work." The blast used in August and September, 1836, was heated.

Before the Doctor's plans for improving his furnace were completed he was called to another world. He died at New York on the 27th of May, 1838, aged sixty-six years and eleven months. He was born at Muhlberg, in the electorate of Saxony, in 1771, and came to this country when about eighteen years old. His remains rest in the family burial vault in the Lutheran cemetery in Queens county, New York.

Prior to his erection of Valley furnace Dr. Geissenhainer had been engaged in the development of the iron and coal resources of Pennsylvania. As early as 1811 he was associated with Peter Karthaus, of Baltimore, in the mining of bituminous coal in Clearfield county, and a few years later in the ownership of a charcoal furnace in that county. For two or three years before 1830 he owned and operated a small charcoal furnace in Schuylkill county, and it was near this furnace that he afterwards built Valley furnace. Attached to the charcoal furnace was a puddling furnace. He was the pioneer in the development of the Silver creek anthracite coal mines, the projector of the Schuylkill Valley railroad, and the sole owner of the Silver Creek railroad. Dr. Geissenhainer was, as will be seen, a man of great enterprise. His memory as the first successful manufacturer of pig iron with anthracite coal and the hot-blast is entitled to greater honor than it has yet received.

On the 28th of September, 1836, when Dr. Geissenhainer's Valley furnace was successfully making pig iron, and almost three years after the Doctor had obtained a patent for his invention, George Crane, the owner of several furnaces at Yniscedwin, in South Wales, obtained a patent from the British government for the application of the hot-blast to the smelting of iron ore with anthracite coal. On the 7th of February, 1837, he successfully commenced the use of anthracite with the hot-blast at one of his furnaces, obtaining 36 tons a week. In May of that year Solomon W. Roberts, of Philadelphia, visited his works and witnessed the complete success of the experiment, which was the first successful experiment with anthracite coal in a blast furnace in Europe.

Mr. Crane endeavored to obtain a patent in this country for his application of the hot-blast to anthracite coal in the blast furnace, but was unsuccessful, Dr. Geissenhainer's invention being accorded priority. His patent, which was only for the United States, was purchased from his executors in 1838 by Mr. Crane, who, in November of that year, patented some additions to it in this country. The patents could not be enforced here, but Mr. Crane compelled the ironmasters of Great Britain to pay him for the use of his invention. Dr. Geissenhainer never attempted to enforce his patent. The consideration which his executors received from Mr. Crane was $1,000 and the privilege of erecting, free of royalty, fifteen furnaces for the use of anthracite coal with the hot-blast. The following advertisement by Mr. Crane's agents in this country we take from a Philadelphia newspaper published in December, 1839:

ANTHRACITE IRON.—The subscribers, agents of George Crane, Esq., are prepared to grant licenses for the manufacture of iron with anthracite coal, under the patent granted to Mr. Crane by the United States, for smelting iron with the above fuel, in addition to which Mr. Crane holds an assignment of so much of the patent granted to the late Reverend Dr. Geissenhainer as pertains to making iron with anthracite coal. The charge will be 25 cents per ton on all thus manufactured. It has been completely successful both in Wales and at Pottsville, one furnace at the latter place yielding an average product of 40 tons per week of excellent iron. All persons are cautioned against infringing upon either of the above patents. Any application of hot-blast in the smelting of iron ore with anthracite coal, without a license, will be an infringement, and will be treated accordingly. Apply to A. & G. RALSTON & CO.,
dec 9—1m 4 South Front st.

Mr. Crane was born about 1785 at Bromsgrove, in Worcestershire, England, whence he removed in 1824 to Wales.

Two interesting experiments in the use of anthracite coal in the blast furnace were made in this country about the time that Dr. Geissenhainer was successful with his experiment at Valley furnace. In 1836 and 1837 John Pott experimented at Manheim furnace, at Cressona, in Schuylkill county, with anthracite coal as a fuel for smelting iron ore. He first used a mixture of anthracite coal and charcoal with cold-blast. The results accomplished were so encouraging that he added a hot-blast and gradually reduced the proportion of charcoal until only anthracite was used. This he used alone and successfully for a short time. But the blast was too weak, and the furnace was not long in operation. Before necessary improvements could be made it was destroyed by a freshet. In 1837 Jarvis Van Buren, acting for a company, built a furnace at South Easton, in Northampton county, for the purpose or experimenting with anthracite coal. Early in 1838 he was successful in making 20 tons of pig iron, when further operations were stopped in consequence of the blast being too weak. We are not informed whether it was hot or cold.

It is claimed that a successful experiment in the manufacture of pig iron with anthracite coal was made in 1837 by a Mr. Bryant, in a foundry cupola at Manayunk, near Philadelphia. The blast used was produced by "wooden bellows." A few tons of the iron made were used by Parke & Tiers, the owners of the foundry, "and proved to be of good gray quality and of uncommon strength." The experiment was conducted under the auspices of this firm and of Mr. Abraham Kunzi, of the firm of Farr & Kunzi, manufacturing chemists, of Philadelphia. We cannot learn whether the blast was hot or cold.

The record which we shall now give of the successful use of anthracite coal in American furnaces, after Dr. Geissenhainer and George Crane had established the practicability of such use, will embrace only a few of the early anthracite furnaces, and this we condense from Walter R. Johnson's *Notes on the Use of Anthracite*, published in 1841, and from William Firmstone's *Sketch of Early Anthracite Furnaces*, published in the third volume of the *Transactions of the American Institute of Mining Engineers.*

Late in 1837 Joseph Baughman, Julius Guiteau, and Henry High, of Reading, experimented in smelting iron ore with anthracite coal in the old furnace of the Lehigh Coal and Navigation Company at Mauch Chunk, using about 80 per cent. of anthracite. The results were so encouraging that they built a small water-power furnace near the Mauch Chunk weigh-lock, which was completed in July, 1838. Blast was applied to this furnace on August 27, and discontinued on September 10, the temperature being heated up to about 200° Fahrenheit. The fuel used was mainly anthracite, but not exclusively. A new heating apparatus was procured, placed in a brick chamber at the tunnel-head, and heated by a flame therefrom. Blast was applied late in November, 1838, the fuel used being anthracite exclusively, and "the furnace worked remarkably well for five weeks," up to January 12, 1839, when it was blown out for want of ore. Some improvements were made, and on July 26, 1839, the furnace was again put in blast, and so continued until November 2, 1839. Mr. F. C. Lowthorp, of Trenton, was one of the partners at this time. For "about three months" no other fuel than anthracite was used, the temperature of the blast being 400° to 600°. About 100 tons of iron were made.

The next furnace to use anthracite was the Pioneer, built in 1837 and 1838 at Pottsville, by William Lyman, of Boston, under the auspices of Burd Patterson, and blast was unsuccessfully applied on July 10, 1839. Benjamin Perry then took charge of it, and blew it in on October 19, 1839, with complete success. This furnace was blown by steam-power. The blast was heated in ovens at the base of the furnace, with anthracite, to a temperature of

600°. The product was about 28 tons a week of good foundry iron. The furnace continued in blast for some time. A premium of $5,000 was paid by Nicholas Biddle and others to Mr. Lyman, as the first person in the United States who had made anthracite pig iron continuously for one hundred days.

Danville furnace, in Montour county, was successfully blown in with anthracite in April, 1840, producing 35 tons of iron weekly with steam-power. Roaring Creek furnace, in Montour county, was next blown in with anthracite on May 18, 1840, and produced 40 tons of iron weekly with water-power.

A charcoal furnace at Phœnixville, built in 1837 by Reeves, Buck & Co., was blown in with anthracite on June 17, 1840, by William Firmstone, and produced from 28 to 30 tons of pig iron weekly with water-power. The hot-blast stove, which was planned and erected by Julius Guiteau, of the Mauch Chunk furnace, was situated on one side of the tunnel-head, and heated by the flame of the furnace. This furnace continued in blast until 1841.

Columbia furnace, at Danville, was blown in with anthracite by Mr. Perry on July 2, 1840, and made from 30 to 32 tons of iron weekly, using steam-power.

The next furnace to use anthracite, and the last one we shall mention, was built at Catasauqua, for the Lehigh Crane Iron Company, in 1839, by David Thomas, who had been associated with Mr. Crane in his experiments at Yniscedwin. It was successfully blown in by him on the 3d of July, 1840, and produced 50 tons a week of good foundry iron, water-power being used. This furnace was in active use until 1879, when it was torn down. Mr. Firmstone says that "with the erection of this furnace commenced the era of higher and larger furnaces and better blast machinery, with consequent improvements in yield and quality of iron produced."

David Thomas is still living at Catasauqua in the full enjoyment of all his faculties—the oldest ironmaster in the United States in length of service, and, next to Peter Cooper, the oldest in years. He is now 87 years old. He was born on November 3, 1794, at a place called, in English, Grey House, within two and a half miles of the town of Neath, in the county of Glamorgan, South Wales. He landed in the United States on June 5, 1839, and on July 9 of that year he commenced to build the furnace at Catasauqua. Father Thomas's character and services to the American iron trade are held in high honor by every American iron and steel manufacturer. William Cullen Bryant and Mr. Thomas were born on the same day.

In 1835 the Franklin Institute, of Philadelphia, offered a premium of a gold medal "to the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than anthracite coal, the quantity to be not less than twenty tons," but we cannot learn that it was ever awarded to any of the persons who were instrumental in establishing the manufacture of anthracite pig iron in this country.

The discovery that anthracite coal could be successfully used in the manufacture of pig iron gave a great impetus to the iron industry in Maryland, New Jersey, and New York, as well as in Pennsylvania. In 1840 there were only six furnaces in the United States which used anthracite coal, and they were all in Pennsylvania. The first anthracite furnace outside of Pennsylvania was built at Stanhope, New Jersey, in 1840 and 1841, by the Stanhope Iron Company, and it was successfully blown in on April 5, 1841. On the 1st of April, 1846, there were forty-two furnaces in Pennsylvania and New Jersey which used anthracite coal as fuel, their annual capacity being 122,720 gross tons. In 1856 there were 121 anthracite furnaces in the country which were either "running or in running order"—ninety-three in Pennsylvania, fourteen in New York, six in Maryland, four in New Jersey, three in Massachusetts, and one in Connecticut. Soon after 1856 many other furnaces were built to use anthracite as fuel.

Although the revolution to which we have referred properly dates from the first successful use of anthracite coal in the blast furnace, this fuel had been previously used in a small way in our country in other ironmaking operations. Its use in these operations became general about the time when pig iron was made with it.

The first use of anthracite coal in connection with the manufacture of iron in the United States dates from 1812, in which year Colonel George Shoemaker, of Pottsville, Pennsylvania, loaded nine wagons with coal from his mines at Centreville, and hauled it to Philadelphia, where with great difficulty he sold two loads at the cost of transportation and gave the other seven loads away. He was by many regarded as an impostor for attempting to sell stone to the public as coal. Of the two loads sold, one was purchased by White & Hazard, for use at their wire works at the Falls of Schuylkill, and the other was purchased by Malin & Bishop, for use at the Delaware County rolling mill. By the merest accident of closing the furnace doors Mr. White obtained a hot fire from the coal, and from this occurrence, happening in 1812, we may date the first successful use of anthracite coal in the manufacture of iron in this country and in other American manufactures. At both the establishments mentioned it was used in their heating furnaces. Previous to this time bituminous coal from Virginia and Great Britain had been relied upon for manufacturing purposes in the Atlantic States in all cases where wood was not used.

In the latter part of 1823 the Boston Iron Company, owning the Boston iron works, obtained a full cargo of Lehigh anthracite coal, for use in heating iron to be rolled in its mill, and for smith-work. A short time previous to this transaction, and in the same year, Cyrus Alger, of South Boston, obtained a lot of about thirty tons of Lehigh coal, which he used in a cupola for melting iron for castings.

Anthracite coal for the generation of steam was first used in this country in January, 1825, under the boilers of the rolling mill at Phœnixville, of which Jonah and George Thompson, of Philadelphia, were the proprietors. It is also claimed that, two years later, in 1827, the first use of anthracite coal in the puddling furnace in this country was at the same rolling mill, Jonah and George Thompson still being the proprietors. The use of anthracite for puddling did not become general until about 1840. In 1839 anthracite coal was used in puddling at the Boston iron-works by Ralph Crooker, the superintendent. About 1836 Thomas and Peter Cooper, brothers, used anthracite in a heating furnace at their rolling mill in Thirty-third street, near Third avenue, New York, and about 1840 they began to puddle with anthracite. In April, 1846, there were twenty-seven rolling mills in Pennsylvania and New Jersey which used anthracite coal.

The following notice of the success of the Messrs. Thompson in the use of anthracite coal for the production of steam appeared at the time in a newspaper published at West Chester, Pennsylvania. "We understand that the Messrs. Thompson, at the Phœnix nail-works, on French creek, have fully succeeded in constructing a furnace for a steam engine calculated for the use of anthracite coal, and in discovering a mode by which this fuel may be most advantageously applied to that important purpose. We would heartily congratulate the eastern section of our state upon this valuable discovery. Nothing within our knowledge has occurred of recent date which can have a more auspicious influence upon our manufacturing interests."

THE MANUFACTURE OF IRON IN THE UNITED STATES WITH BITUMINOUS COAL.

It is remarkable that the introduction of bituminous coal in the blast furnaces of this country should have taken place at so late a day in our history, and within the memory of men who are not yet old. Bituminous coal had been discovered in the United States long before any attempt was made to use it in our blast furnaces, and Great Britain had taught us while we were still her colonies that it could be so used. In 1735 Abraham Darby, at his furnace at Coalbrookdale, in Shropshire, had successfully made pig iron with coke as fuel; in 1740 a coke furnace was built at Pontypool, in Monmouthshire; and in 1796 charcoal furnaces had been almost entirely abandoned in Great Britain. Our delay in following the example of the mother country may be variously explained. There was a lack of transportation facilities for bringing iron ore and coke together; not all of the bituminous coal that had been discovered was suitable for making good coke; the manufacture of coke was not well understood; the country had an abundance of timber for the supply of charcoal; and, finally, a prejudice existed in favor of charcoal pig iron and of bar iron hammered in charcoal forges.

The introduction about 1840 of bituminous coal as a fuel in American blast furnaces was naturally preceded by many experiments in its use, which were attended with varying success, but none of them with complete success. It appears to be mathematically certain that down to 1835 all of these experiments had been unsuccessful, as in that year the Franklin Institute, of Philadelphia, offered a premium of a gold medal "to the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity to be not less than twenty tons." The Institute would not have been likely to make this offer if even so small a quantity as twenty tons of pig iron had been made in one furnace with bituminous coal, either coked or uncoked.

In a report by a committee of the Senate of Pennsylvania, of which Hon. S. J. Packer was chairman, read in the Senate on March 4, 1834, it was stated that "the coking process is now understood, and our bituminous coal is quite as susceptible of this operation, and produces as good coke, as that of Great Britain. It is now used to a considerable extent by our iron manufacturers in Centre county and elsewhere." It is certain that, at the time this report was written, coke could not have been used in blast furnaces in any other way than as a mixture with charcoal, and then only experimentally.

The offer of the gold medal by the Franklin Institute doubtless assisted in stimulating action upon a subject which had already attracted much attention. In the year in which this premium was offered, that accomplished furnace manager, William Firmstone, was successful in making good gray forge iron for about one month at the end of a blast at Mary Ann furnace, in Huntingdon county, Pennsylvania, with coke made from Broad Top coal. This iron was taken to a forge three miles distant and made into blooms. Mr. Firmstone did not claim the medal. He may not have known that a premium had been offered for the achievement which he undoubtedly accomplished.

In a pamphlet published in April, 1836, Isaac Fisher, of Lewistown, Pennsylvania, stated that "successful experiments have lately been tried in Pennsylvania in making pig iron with coke." It is probable that Mr. Fisher had in mind Mr. Firmstone's experiment.

William Firmstone was born at Wellington, in Shropshire, England, on October 19, 1810. When quite a young man he was manager at the Lays Works, near Dudley, which were then owned by his uncles, W. & G. Firmstone. He emigrated to the United States in the spring of 1835. After filling many responsible positions in connection with the manufacture of pig iron he died at his residence near Easton on September 11, 1877, and is buried in the cemetery at Easton. He was one of the first to introduce the hot-blast in the United States, having successfully added this improvement to Vesuvius furnace, in Lawrence county, Ohio, in 1836. In 1839 he added a hot-blast to Karthaus furnace, in Pennsylvania.

In 1836 or 1837 F. H. Oliphant, a skillful ironmaster, made at his furnace called Fairchance, near Uniontown, Fayette county, Pennsylvania, a quantity of coke pig iron in excess of 20 tons, and probably in excess of 100 tons.

He did not, however, long continue to make coke iron, and resumed the manufacture of iron with charcoal. Mr. Oliphant had heard of the offer of the gold medal, and in a letter to the Institute, dated October 3, 1837, he modestly referred to his success in making pig iron with coke, and suggested that possibly he was entitled to the premium. Accompanying his letter was a box of pig iron and the raw materials of its manufacture. We do not learn that he ever received the medal, or that anybody received it.

Between 1836 and 1839 other attempts were made at several furnaces in Pennsylvania to use coke, but the experiments were unsuccessful or unfortunate. The legislature of Pennsylvania passed an act on June 16, 1836, "to encourage the manufacture of iron with coke or mineral coal," which authorized the organization of companies for the manufacture, transportation, and sale of iron made with coke or coal. At Farrandsville, six miles north of Lock Haven, in Clinton county, half a million dollars was sunk by a Boston company in a disastrous attempt to smelt the neighboring ores with coke, and to establish other iron and mining enterprises. This company had commenced operations in the mining of coal as early as 1833. The furnace was blown in in the summer of 1837, and ran probably until 1839. About 3,500 tons of iron were made, but at such great cost, owing to the impurity of the coal and the distance of the ore, that further efforts to make iron with coke were abandoned. At Karthaus, in Clearfield county, the Clearfield Coal and Iron Company, composed of Henry C. Carey, Burd Patterson, John White, and others, succeeded in 1839, under the management of William Firmstone, in making pig iron with coke in a furnace which was built in 1836 by Peter Ritner (brother of Governor Ritner) and John Say, but at the close of the year the whole enterprise was abandoned, owing to the lack of proper transportation facilities. A furnace at Frozen run, in Lycoming county, made some pig iron with coke in 1838, but in 1839 it was using charcoal. The furnaces at Farrandsville and Karthaus were both supplied with hot-blasts—the former in 1837 and the latter in 1839. The apparatus for that at Farrandsville was made at Glasgow, and was the best then known.

The first notable success in the use of bituminous coal in the blast furnace in this country was achieved at three furnaces in western Maryland. Lonaconing furnace, in the Frostburg coal basin, on George's creek, eight miles northwest of Frostburg, in Alleghany county, was built in 1837 by the George's Creek Company, to use coke, and in June, 1839, it was making about 70 tons per week of good foundry iron. Alexander says that "the air was heated by stoves placed near the tuyere arches, and attained a temperature of 700 degrees Fahrenheit." The furnace was blown by an engine of 60-horse power. In the same coal basin, on the south branch of Jenning's run, nine miles northwest of Cumberland, two large blast furnaces were built in 1840 by the Mount Savage Company to use the same fuel. These furnaces were for several years successfully operated with coke.

But the use of coke did not come rapidly into favor, and many experiments with it were attended with loss. It was not until after 1850 that its use began to exert an appreciable influence upon the manufacture of pig iron. In 1849 there was not one coke furnace in Pennsylvania in blast. Thus far coke had not noticeably contributed to the revolution to which we have referred in the preceding chapter. But in 1856 there were twenty-one furnaces in Pennsylvania and three in Maryland which were using coke. After 1856 the use of this fuel rapidly increased in Pennsylvania, and was extended to other states.

While the effort was being made in a few localities in Pennsylvania and Maryland to introduce the use of coke in the blast furnace, attention was also directed to the possibility of using uncoked coal for the same purpose. Alexander says that the proprietors of Lonaconing furnace, in western Maryland, used raw coal before 1840. He leaves the reader to infer that it was successfully used, but he probably wrote from imperfect information. Some unsuccessful experiments were made with raw coal in Clarion county, Pennsylvania, about 1840. In the sketch of Mercer county, Pennsylvania, in Day's *Historical Collections*, printed in 1843, it is stated that, "in the vicinity of Sharon, on the Pittsburgh and Erie canal, exists a most valuable bed of coal of peculiar quality, between anthracite and bituminous, without the least sulphur. It has been tried successfully for smelting iron in a common charcoal furnace." It is not certain that the furnace referred to was in Mercer county. The coal mentioned is now classed among bituminous varieties. At Arcole furnace, in Lake county, Ohio, operated by Wilkeson & Co., raw coal from Greenville, Mercer county, Pennsylvania, was experimented with about 1840. John Wilkeson, one of the owners of the furnace at that time, writes us that the experiment "met with a small measure of success." Doubtless the several experiments mentioned were not the only ones that were made with raw coal before success in its use was fully achieved; and doubtless, too, none of the experiments mentioned produced any more satisfactory results than the qualified success attained at Arcole furnace.

The first truly successful use of raw bituminous coal in the blast furnace occurred in the autumn of 1845. It is circumstantially described in the following extract from a pamphlet entitled *Youngstown, Past and Present*, published in 1875: "In July, 1845, Himrod & Vincent, of Mercer county, Pennsylvania, blew in the Clay furnace, not many miles from the Ohio line, on the waters of the Shenango. About three months afterwards, in consequence of a short supply of charcoal, as stated by Mr. Davis, their founder, a portion of coke was used to charge the furnace. Their coal belongs to seam No. 1, the seam which is now used at Sharon and Youngstown, in its raw state, variously known as 'free-burning splint,' or 'block coal,' and which never makes solid coke. A difficulty soon occurred with the cokers, and, as Mr. Himrod states, he conceived the plan of trying his coal without coking. The furnace continued to work well, and to produce a fair quality of metal. It is admitted that Mr. David Himrod, late of Youngstown, produced the first metal with raw coal, about the close of the year 1845." The furnace here alluded to was situated on Anderson's run, in Mercer county, Pennsylvania, about two and one-half miles southeast of Clarksville, and was built in 1845. It has been abandoned for many years. In the chapter relating to Michigan we have mentioned the part taken by this furnace at an early day in smelting Lake Superior ores with the block coal of the Shenango valley.

While Himrod and Vincent were using the raw coal of the Shenango valley at Clay furnace, Messrs. Wilkeson, Wilkes & Co., of Lowell, in Poland township, Mahoning county, Ohio, were building Mahoning furnace, as related in the chapter devoted to Ohio, expressly to use in its raw state coal of the same quality from their mine near Lowell. This furnace was successfully blown in with this fuel by John Crowther on the 8th of August, 1846. The *Trumbull Democrat*, of Warren, Ohio, for August 15, 1846, in an account of the blowing in of Mahoning furnace, states that "to these gentlemen (Wilkeson, Wilkes & Co.) belongs the honor of being the first persons in the United States who have succeeded in putting a furnace in blast with raw bituminous coal."

John Crowther was an Englishman, born at Broseley, in Shropshire, on May 7, 1797. He emigrated to the United States in 1844, immediately prior to which time he had been the manager of seven blast furnaces in Staffordshire—five at Stowheath and two at Osier Bed. Prior to his connection with the Lowell furnace he had been employed as manager of the furnaces at Brady's Bend. He adapted many furnaces in the Mahoning and Shenango valleys to the use of block coal, and instructed three of his sons in their management, namely, Joshua, Joseph J., and Benjamin. He died on April 15, 1861, at Longton, in Staffordshire, England, where he is buried.

After it had been demonstrated at Clay and Mahoning furnaces that the block coal of the Shenango and Mahoning valleys could be used in the manufacture of pig iron, other furnaces in these two valleys were built to use this fuel, and some charcoal furnaces were altered to use it. In 1850 there were, however, only four furnaces in the Mahoning valley and only seven in the Shenango valley which used raw coal. After 1850, and especially after the introduction into these valleys of Lake Superior ores, about 1856, the use of raw coal greatly increased. In 1856 six furnaces in Pennsylvania and thirteen in Ohio were using this fuel. Some progress was afterwards made in its use in other states, particularly in Indiana, but down to 1880 its use had been mainly confined to the two valleys mentioned.

The American Iron and Steel Association has published a table which exhibits the production of pig iron in this country in each year from 1854 to 1880, classified according to the fuel used. So much of this table is here reproduced as will show the growth of the manufacture of pig iron with anthracite and bituminous coal since 1854, and also the period at which the use of bituminous coal in the blast furnace overtook that of anthracite coal.

Years.	Anthracite.	Charcoal.	Bituminous coal and coke.	Total.
	Net tons.	*Net tons.*	*Net tons.*	*Net tons.*
1854	339, 435	342, 298	54, 485	736, 218
1855	381, 866	339, 922	62, 390	784, 178
1856	443, 113	370, 470	69, 554	883, 137
1872	1, 369, 812	500, 587	984, 159	2, 854, 558
1873	1, 312, 754	577, 620	977, 904	2, 868, 278
1874	1, 202, 144	576, 557	910, 712	2, 689, 413
1875	908, 046	410, 990	947, 545	2, 266, 581
1876	794, 578	308, 649	990, 009	2, 093, 236
1877	934, 797	317, 843	1, 061, 945	2, 314, 585
1878	1, 092, 870	293, 399	1, 191, 092	2, 577, 361
1879	1, 273, 024	358, 873	1, 438, 978	3, 070, 875
1880	1, 807, 651	537, 558	1, 950, 205	4, 295, 414

Some of the pig iron classed above as having been produced with anthracite and bituminous coal, respectively, was produced with a mixture of these fuels, the quantity of pig iron so produced being mainly represented in the anthracite column. The mixed fuel referred to was not used to any considerable extent until within the past few years.

Before the close of the charcoal era steam had been applied to the blowing of American furnaces, but water-power was still in general use. The necessity of increasing the blast, and other considerations, soon led to the more general use of steam blowing engines in connection with anthracite and bituminous furnaces. Another improvement in blast-furnace management also had its beginning about the close of the charcoal era, namely, the utilization of the combustible gases emitted from blast furnaces. These gases were first used to heat the boilers for the blowing engines, and afterwards to heat the hot-blast stoves.

Bituminous coal was used at an early day in the heating furnaces attached to American rolling and slitting mills, and in 1817, when the rolling mill was established at Plumsock, in Fayette county, Pennsylvania, it was used in puddling furnaces. It was not, however, until about 1830, when rolling mills became numerous at Pittsburgh, that the use of bituminous coal in these establishments assumed noteworthy importance.

THE MANUFACTURE OF BLISTER AND CRUCIBLE STEEL IN THE UNITED STATES.

Steel was manufactured in a small way in several of the American colonies, either "in the German manner" or by the more clearly defined cementation process. We have in preceding chapters incidentally recorded some of the earliest attempts that were made to establish the manufacture of steel by these primitive methods. In this and the next chapter we will endeavor to present in sufficient detail the leading facts in the development of the present magnificent steel industry of our country. To do this we must first briefly notice the very insignificance of our small steel industry as it existed in colonial times and long after the close of the Revolutionary struggle.

Bishop states that the first suggestion of the manufacture of steel in the colonies was made in 1655, when John Tucker, of Southold, on Long Island, informed the general court of Connecticut "of his abilitie and intendment to make steele there or in some other plantation in the jurisdiction, if he may have some things granted he therein propounds." In October, 1655, and in May, 1656, special privileges were granted to the petitioner, but we are not told whether he ever made any steel. In 1736 Joseph Higby, of Simsbury, Connecticut, represented that he had, "with great pains and cost, found out and obtained a curious art by which to convert, change, or transmit common iron into good steel, sufficient for any use, and was the very first that ever performed such an operation in America." Several smiths testified to the excellent quality of his steel. Certain privileges were granted to him and his partner, Joseph Dewey, of Hebron, but we do not learn that they afterwards made any steel. In 1750 steel of good quality was made "from the crude metal" by D. J. Styles, at New Milford, in Litchfield county, Connecticut. Some time previous to 1750 a Mr. Eliot owned a steel furnace at Killingworth, and it was in this furnace that Rev. Jared Eliot, father of the owner, succeeded in 1761 in converting into good steel a bar of iron made in a common bloomary from magnetic sand, for which achievement he received a gold medal from the London Society of Arts.

In 1750 Massachusetts had one steel furnace. Bishop tells us that in 1787 the manufacture of steel was introduced in the town of Easton, in Massachusetts, by Eliphalet Leonard. "The article was made in considerable amount, and cheaper than imported steel," but it was inferior to foreign steel for edge tools and cutlery. This was doubtless cemented steel. About the same time some steel was made at Canton, in the same state, "from crude iron by the German process."

Peter Townsend, who became the proprietor of the Sterling iron works in New York before the Revolution, produced in 1776 the first steel made in that province. It was made "at first from pig and afterwards from bar iron, in the German manner." Blister steel was made in 1810 by Peter Townsend, Jr., which is said to have been equal to steel made from Dannemora iron in the manufacture of edge tools. At Amenia, in Dutchess county, New York, steel was made for the use of the Continental army.

New Jersey had one steel furnace in 1750. Steel was made at Trenton during the Revolution, "but the business afterwards declined."

Pennsylvania had a steel furnace in Chester county, called Vincent's, before 1750, and in that year it had two steel furnaces—both at Philadelphia. Concerning one of these, William Branson's, Richard Hockley writes to Thomas Penn on June 3, 1750: "As to steel, Mr. Branson says the sort he made, which was blistered steel, 10 tons would be ten years in selling." The other furnace, Stephen Paschal's, which was built in 1747, was owned in 1787 by Nancarrow & Matlock, when it was visited by General Washington, and is said to have been "the largest and best in America." In 1770 Whitehead Humphreys was the proprietor of a steel furnace on Seventh street, in Philadelphia. During the Revolution he made steel for the Continental army from Andover iron. In 1786 the legislature of Pennsylvania loaned £300 to Mr. Humphreys for five years to aid him in making steel from bar iron "as good as in England."

During the Revolution Henry Hollingsworth, at Elkton, in Cecil county, Maryland, manufactured muskets for the Continental army. Some of his bayonets were complained of as being too soft, "which he ascribed to the bad quality of the American steel with which they were pointed." Bishop does not mention any steel furnace in Maryland, and we are therefore unable to conjecture where Mr. Hollingsworth obtained his poor steel. We are also without positive information concerning the colonial or Revolutionary steel industry of Virginia and other southern colonies. In most of these colonies bounties were offered at the beginning of the Revolution for the establishment of steel furnaces as well as other manufacturing enterprises.

In the celebrated report of Alexander Hamilton, dated December 5, 1791, it is stated that "steel is a branch which has already made a considerable progress, and it is ascertained that some new enterprises on a more extensive scale have been lately set on foot." In the same year, 1791, in a reply to Lord Sheffield's *Observations on the Commerce of the United States*, Tench Coxe stated that "about one-half of the steel consumed in the United States is home-made, and new furnaces are building at this moment. The works being few, and the importations ascertained, this fact is known to be accurate." The works here referred to were all cementation furnaces, which produced blister steel.

In 1805 there were two steel furnaces in Pennsylvania, which produced annually 150 tons of steel. One of these was in Philadelphia county. In 1810 there were produced in the whole country 917 tons of steel, of which

Pennsylvania produced 531 tons in five furnaces—one at Philadelphia and one each in Philadelphia, Lancaster Dauphin, and Fayette counties. The remainder was produced in Massachusetts, Rhode Island, New Jersey, Virginia, and South Carolina, each state having one furnace. In 1813 there was a steel furnace at Pittsburgh, owned by Tuper & McKowan, which was the first in that city. Tench Coxe declared in this year that the manufacture of "common steel, iron wire, and edge tools" had been greatly advanced since 1810.

In 1831 a convention of the friends of American industry assembled at New York, at which were submitted many able reports upon the iron and steel industries of the country as they existed at that time. From one of these reports, prepared, we believe, by John R. Coates, of Philadelphia, we learn that there were then in the United States fourteen steel furnaces, distributed as follows: Two at Pittsburgh, one at Baltimore, three at Philadelphia, three in New York, one in York county, Pennsylvania, one at Troy, New York, two in New Jersey, and one at Boston. The report stated that "these furnaces are known to be now in operation, and of a capacity sufficient to supply more than 1,600 tons of steel annually, an amount equal to the whole importation of steel of every kind." The report continued: "But it should be observed that steel for common agricultural purposes is not the best, although it is most used; and that American is quite equal to English steel used for such purposes in England. American competition has excluded the British common blister steel altogether. The only steel now imported from Great Britain is of a different and better quality than that just mentioned." The common blister steel of American manufacture which is above referred to was used for plow-shares, shovels, scythes, and cross-cut and mill saws.

The better qualities of steel which were not made in this country in 1831, but were imported from Europe, almost entirely from England, were known as (1) best blister steel, made from iron from the Dannemora mines in Sweden; (2) shear steel, of the same origin; and (3) cast steel, made in crucibles. Concerning blister steel of the best quality the report from which we have quoted says that "steel is now made at Pittsburgh, and may be made in New York and Connecticut, bearing a fair comparison with the best hoop L, or Dannemora steel. No difference is observed where trials have been made without disclosing to the judges the origin of either." The report adds that iron equal to Swedish for the manufacture of steel had been recently manufactured "by improved processes from the ore of Juniata, and both sides of the line between New York and Connecticut." Shear steel was the best blister steel of the cementation furnace reworked under a hammer into bars convenient for the manufacture of coarse cutlery and edge tools. The manufacture of this steel was then about being introduced into this country. The report says: "England has hitherto monopolized this branch also, from being in possession of the only European steel that would bear the expense of preparation, and from the perfection of her machinery. She has now the honor of transferring a portion of her experience and skill to the United States." Cast steel, which was then made only from the best blister steel, was not made in the United States. Several attempts to make it with profit had been unfortunate in their results. "The causes of failure," says the report, "were, first, the want of the best quality of blister steel, at a reasonable price, and, second, the want, or expense, of crucibles of proper quality, wherein the blister steel is to be melted and smelted. Black lead and a variety of clays have been tried, but the weakness of these materials has heretofore caused a loss to the manufacturer." The English Stourbridge clay was the only clay which in 1831 was known to possess the qualities required for crucibles. The report says that "the explorations of the present year have disclosed the existence of clay analogous to that of Stourbridge," the discoveries being made in Centre, Clearfield, and Lycoming counties in Pennsylvania, and in the vicinity of Baltimore. The expectations created by these discoveries were destined to disappointment.

From 1831, the date of the report from which we have just quoted, to 1860 but little progress was made in developing the manufacture of the finer qualities of steel in this country.

The following is a list of all the works in Pennsylvania that were engaged in the conversion of steel in 1850, with their product: James Rowland & Co., Kensington, (Philadelphia,) 600 tons; J. Robbins, Kensington, 500 tons; Earp & Brink, Kensington, 100 tons; Robert S. Johnson, Kensington, 400 tons; W. & H. Rowland, Oxford, (Philadelphia,) 700 tons; R. & G. D. Coleman, Martic, Lancaster county, 400 tons; R. H. & W. Coleman, Castle Fin, York county, 100 tons; Singer, Hartman & Co., Pittsburgh, 700 tons; Coleman, Hailman & Co., Pittsburgh, 800 tons; Jones & Quigg, Pittsburgh, 1,200 tons; Spang & Co., Pittsburgh, 200 tons; G. & J. H. Shoenberger, Pittsburgh, 200 tons; S. McKelvy, Pittsburgh, 178 tons; total, thirteen works, with a product of 6,078 tons. Of this quantity only 44 tons was cast steel. The foregoing information is not found in the census of 1850, but was obtained by an association of Pennsylvania ironmasters. The census of that year greatly understated the extent of our steel industry, and erroneously makes no mention of the manufacture of steel in any other state than Pennsylvania.

From about 1830 to 1860 many attempts were made at Pittsburgh to produce the various grades of steel. Between 1828 and 1830 an Englishman, named Broadmeadow, and his son, who had established a manufactory of files and rasps, made blister steel, and about 1831 they made some cast steel in pots of their own manufacture. Their attempt to manufacture cast steel was a failure. Josiah Ankrim & Son, file-makers, are said to have succeeded in making their own steel about 1830, but by what process is not stated. In 1831 Messrs. Wetmore & Havens successfully produced blister steel. In 1833 the firm of G. & J. H. Shoenberger commenced to manufacture blister steel, and in 1841 Patrick and James Dunn attempted the manufacture of crucible cast steel for this firm.

This last enterprise was abandoned in a year or two. "The crucibles employed were made of American clay, and, as may be supposed, were ill-suited to the purpose required." The firm continued to make blister steel until 1862, when its further manufacture was abandoned. It used Juniata blooms exclusively. About 1840 the firm of Isaac Jones & William Coleman was formed to manufacture blister steel, which business was successfully prosecuted until 1845, when the firm was dissolved, Mr. Jones retiring. In the same year Jones & Quigg built the Pittsburgh steel works, also to manufacture blister steel. Mr. Coleman continued alone the manufacture of blister steel until 1846, when a partnership was formed under the name of Coleman, Hailman & Co. Both of these new firms were successful in making blister steel of good quality. They were also successful in manufacturing some cast steel of a low grade. The first slab of cast plow steel ever rolled in the United States was rolled by William Woods, at the steel works of Jones & Quigg, in 1846, and shipped to John Deere, of Moline, Illinois. About 1846 the firm of Tingle & Sugden, file-makers, made its own steel. This was cast steel. The firm is also reported to have made some cast steel for sale. Juniata iron was used by all of these manufacturers.

In 1852 McKelvy & Blair, of Pittsburgh, who had commenced the manufacture of files in 1850, made cast steel of good quality, but not always of the best quality. It was, however, of a quality so creditable, and so uniformly superior to any that had previously been made at Pittsburgh, that the firm may be regarded as the pioneer in the production of cast steel in large quantities in that city. In 1853 the firm of Singer, Nimick & Co., of Pittsburgh, which had been organized in 1848 for the manufacture of blister steel, and in 1855 Isaac Jones, then doing business in his own name, were successful in producing the usual grades of cast steel for saw, machinery, and agricultural purposes, but they did not make tool steel of the best quality as a regular product. That honor was reserved for the firm of Hussey, Wells & Co., which began business in 1859, and in the following year was successful in making crucible cast steel of the best quality as a regular product. This was done with American iron. In 1862 the firm of Park, Brother & Co., also of Pittsburgh, accomplished the same achievement, also with American iron. These were the first firms in the country to meet with complete success in this difficult department of American manufacturing enterprise.

For many of the foregoing details concerning the manufacture of steel at Pittsburgh we are indebted to an anonymous publication, entitled *Pittsburgh, its Industry and Commerce*, published in 1870, and to George H. Thurston's *Pittsburgh and Allegheny in the Centennial Year.*

While these experiments in the manufacture of the best qualities of steel were being made at Pittsburgh, other localities were engaged in making similar experiments. The most important of these was conducted by the Adirondack Iron and Steel Company, whose works were at Jersey City, New Jersey. They were built in 1848 to make blister steel from charcoal pig iron made at Adirondack, Essex county, New York, and also to make cast steel. The pig iron was puddled with wood at Adirondack, and then drawn into bars under a hammer, which were sent to Jersey City, where they were converted into blister steel. An attempt to make cast steel by melting the blister steel in clay crucibles was a failure, but subsequently cast steel of good quality was made in black lead crucibles. This result was reached as early as February, 1849, and possibly a few months earlier. Of the excellent quality of the cast steel manufactured at this time at these works there is abundant evidence in the testimony of Government experts and of many consumers, all of which is now before us. It was used for chisels, turning and engravers' tools, drills, hammers, shears, razors, carpenters' tools, etc. Its manufacture was continued with encouraging results until 1853, when the business was abandoned by the company. It had not proved to be profitable, partly because of the prejudice existing against American cast steel. The works were then leased for ten years, during which they were managed with varying success. James R. Thompson was the manager from 1848 to 1857. In 1863 they passed into the hands of Dudley S. Gregory, one of the original stockholders, and were from that time managed with uniform success for the owner by H. J. Hopper. In 1874 Mr. Gregory died, and the works descended to his sons. They are the oldest cast-steel works in the United States, having been continuously employed in the production of this quality of steel since 1849. Mr. Hopper is still their manager.

It is proper to add that, while good cast steel was made from 1849 at the works of the Adirondack Iron and Steel Company, the product was not for many years of uniform excellence. Much of it was good tool steel, but much of it was also irregular in temper. The exact truth appears to be that the cast steel produced during the early years of trial, or from 1849 to 1853, was more uniformly excellent than that which had been produced by earlier or by cotemporary American steel works. This excellence was mainly due to the superiority of Adirondack iron. Since 1852 the Adirondack works have had many rivals in the production of crucible cast steel, the earliest of which have already been described in our reference to Pittsburgh enterprises.

Mr. Thomas S. Blair, of Pittsburgh, has furnished us with the following reminiscences of the American steel industry as it existed about 1850.

The blister steel made at Pittsburgh was sent all over the west, and was used by the country blacksmiths for the pointing of picks, mattocks, etc., and for plating out into rough hoes, etc. It was usually made from Juniata blooms, especially in the period anterior to 1850. After that date Champlain ore blooms were used to a considerable extent. German steel was simply blister steel rolled down. The two leading applications of German steel were springs and plow shares. The business was very large at one time. G. & J. H. Shoenberger pushed this brand vigorously from about 1840 to 1860. Meanwhile quite a number of other concerns entered into the competition at various times.

The Shoenberger experiment in the manufacture of crucible steel failed on account of the inferior quality of the product. The firm were so confident that no iron could be found in this country that could in any respect excel the Juniata iron that, when that article failed to produce steel equal to that of Sheffield, they gave up the manufacture of crucible steel. In the light of the experience gained under the scientific methods which the Bessemer process has made a necessity we now understand that the Shoenbergers could not make good crucible steel out of iron containing two-tenths of one per cent. of phosphorus.

McKelvy & Blair at first made their pots out of Darby and Stannington clay, imported from England. The brilliant success of Joseph Dixon, of Jersey City, New Jersey, in perfecting the manufacture of plumbago crucibles, for which the crucible steel interest in the United States owes him a monument, gave to that firm and to the Jersey City steel works a very valuable lift. With these crucibles and with Adirondack blooms Mr. Thompson made some excellent steel. Along in 1853 and 1854 McKelvy & Blair made steel from the Adirondack blooms which was used in the nail factory of G. & J. H. Shoenberger. The American steel made from American iron was fully up to the English steel in every particular. It may be added, also, that the knives and dies of nail-cutting machines afford an admirable test of endurance in tool steel.

It was not possible for McKelvy & Blair to obtain the Adirondack blooms in any quantity, and they had no other resource than the Champlain and Missouri blooms, all of which produced red-short steel. This, notwithstanding that drawback, found a market so extensive that the firm sent to Sheffield and brought out several skilled workmen, and the business of manufacturing handsomely finished bars, plates, and sheets was fairly inaugurated. The drawbacks, however, of pioneer operations, chief among which was the abominable English system, imported along with the skilled labor, of "working to fool the master," were too much for the financial strength of the firm, and in 1854 they were forced to drop the enterprise.

The manufacture in this country of crucible cast steel of the best grades may be said to have been established on a firm basis after Hussey, Wells & Co., Park, Brother & Co., and Gregory & Co., in the years 1860, 1862, and 1863, respectively, succeeded in making it of uniform quality as a regular product. The event was one of great importance, as it marked the establishment in this country of a new industry which was destined to assume large proportions and to be of immense value. It met a want that had long been felt, and dissipated the long-standing belief that this country possessed neither the iron nor the skill required to make good cast steel. The establishment of this new industry, following closely in the wake of our successful application of anthracite and bituminous coal in the manufacture of pig iron, assisted greatly to advance our metallurgical reputation and to create confidence in our future metallurgical possibilities.

Fifty years ago, when the convention of the friends of home industry met at New York, we were struggling with the difficulties which then prevented the manufacture of blister steel of best quality; now we have not only solved that problem, but twenty years ago we solved the greater problem of the manufacture of crucible steel, and a few years later we achieved the still greater triumph of firmly planting upon American soil the Bessemer steel industry, the establishment of which industry in many countries in late years is justly regarded as constituting a much more important revolution in the production and use of iron and steel than had been created by any preceding influence or combination of influences in any age of the world's history. To this industry we have added the manufacture of steel by the open-hearth, or Siemens-Martin, process—a method of producing steel second only in cheapness and productiveness to the Bessemer process.

THE MANUFACTURE OF BESSEMER STEEL IN THE UNITED STATES.

The Bessemer process for the manufacture of steel consists in forcing streams of cold air, under a very high pressure, into a large pear-shaped vessel called a converter, which has been filled with melted cast iron, by which operation the oxygen of the air combines with and eliminates the carbon and silicon in the iron, the product being decarbonized and desiliconized iron. But, as some carbon is always required to produce steel, a definite quantity of manganiferous pig iron (*spiegeleisen*) or ferro-manganese is added to the contents of the converter while they are still in a state of fusion, by which addition the requisite amount of carbon is obtained, while the manganese liberates whatever oxygen may have remained after the termination of the blast. The final product is Bessemer steel, of a quality or temper corresponding to the character and proportions of the materials used. A distinguishing feature of the Bessemer process consists in the entire absence of any fuel whatever in converting the already melted cast iron into steel—the carbon and silicon in the iron combining with the oxygen of the atmospheric blast to produce an intensely high temperature. The Bessemer converter holds from five to fifteen tons. The charge of cast iron which it receives preliminary to a conversion, or "blow," may be supplied directly from a blast furnace or from a cupola in which pig metal has been melted. The latter method is generally employed in Europe and exclusively employed in the United States.

Sir Henry Bessemer, of London, the inventor of the process which bears his name, commenced in 1854 to experiment in the manufacture of iron for an improved gun. "In the course of his experiments," says Mr. Jeans, in his comprehensive work on *Steel*, "it dawned upon him that cast iron might be rendered malleable by the introduction of atmospheric air into the fluid metal." In 1855 and 1856 patents were granted to Mr. Bessemer for this discovery, but it was not until 1858 that entire success was achieved by him in the conversion of cast iron into cast steel. Nor was this success achieved without the assistance of others—Robert F. Mushet, of Cheltenham, England, and Goran Fredrick Goransson, of Sandviken, Sweden, contributing greatly to this result. It may also be added that many and valuable improvements have been made in the application of the Bessemer process since its successful introduction in Europe and America. These facts, however, detract nothing from the honor that is due to Sir Henry Bessemer, since it is true of all valuable inventions that their value is increased by the ingenuity and skill of those who use them. In addition to discovering that melted cast iron could be decarbonized and rendered malleable by blowing cold air through it at a high pressure, Mr. Bessemer is entitled to the whole credit of suggesting and perfecting the wonderful machinery by which this discovery has been applied to the rapid production of large quantities of Bessemer steel. The purely engineering feats accomplished by him in the development of his invention were essential to its success, and they amaze us by their novelty and magnitude. Those who have never seen this machinery in operation can form but a faint idea of its exquisite adaptation to the purposes to be accomplished. A Bessemer converter, weighing with its contents from 20 to 30 tons, is moved at will on its axis by the touch of a schoolboy, and receives, in response to the same touch, a blast so powerful that every particle of its many tons of metallic contents is heated to the highest temperature ever known in the mechanic arts. The honor of inventing this machinery is all Mr. Bessemer's own.

In 1856 Mr. Bessemer obtained two patents in this country for his invention, but was immediately confronted by a claim of priority of invention preferred by William Kelly, an ironmaster of Eddyville, Kentucky, but a native of Pittsburgh, Pennsylvania. This claim was heard by the commissioner of patents and its justice was conceded, the commissioner granting to Mr. Kelly a patent which took precedence over the patents granted to Mr. Bessemer. The effect of this action by the commissioner was to prevent for several years any serious effort from being made to introduce Mr. Bessemer's process into this country. As a matter of interest and of history we here give a complete account of Mr. Kelly's invention, prepared for these pages by Mr. Kelly himself.

In 1846 I purchased, in connection with my brother, John F. Kelly, a large iron property in Lyon county, Kentucky, known as the Eddyville iron works; and the beginning of 1847 found the firm of Kelly & Co. fairly under way, making pig metal and charcoal blooms. Our forge contained ten forge fires and two large finery, or run-out, fires.

To the processes of manufacture I gave my first and most serious attention; and, after close observation and study, I conceived the idea that, after the metal was melted, the use of fuel would be unnecessary—that the heat generated by the union of the oxygen of the air with the carbon of the metal would be sufficient to accomplish the refining and decarbonizing of the iron. I devised several plans for testing this idea of forcing into the fluid metal powerful blasts of air; and, after making drawings of the same, showed them to my forgemen, not one of whom could agree with me, all believing that I would chill the metal, and that my experiment would end in failure. I finally fixed on a plan of furnace which I thought would answer my purpose. This consisted of a small blast furnace, about 12 feet high, having a hearth and bosh like a common blast furnace. In this I expected to produce decarbonized metal from the iron ore; but, if I failed in this, I could resort to pig metal and thereby have good fluid metal to blow into. The novelty of this furnace was that it had two tuyeres, one above the other. The upper tuyere was to melt the stock; the lower one was fixed in the hearth near the bottom, and intended to conduct the air-blast into the metal. That portion of the hearth in which the lower tuyere was placed was so arranged as to part from the upper portion, and consisted of a heavy cast-iron draw, lined inside with fire-brick, so that, when the iron was blown to nature by the lower tuyere, the draw could be run from under the hearth, and the iron taken out, carried to the hammer, and forged.

I began my experiments with this furnace in October, 1847, but found it impossible to give it sufficient attention, as I had then commenced to build a new blast furnace, the Suwannee, on our property. This occupied so much of my time that I had but little left in which to attend to my new process. In the year 1851, having finished our new blast furnace, I found myself more at leisure, and again directed my attention to my experiments; and, on looking for the cause of failure in my experimental furnace, found that my chief trouble lay in the melting department, not in the more important matter of blowing into the iron, so that the question presented itself to my mind, Why complicate my experiments by trying to make pig metal in a furnace not at all suited to the business? Why not abandon altogether the melting department and try my experiments at our new blast furnace, where I could have the metal already melted and in good condition for blowing into? I fully believed that I could make malleable iron by this process. In my first efforts with this object in view I built a furnace consisting of a square brick abutment, having a circular chamber inside, the bottom of which was concave like a molder's ladle. In the bottom was fixed a circular tile of fire-clay, perforated for tuyeres. Under this tile was an air-chamber, connected by pipes with the blowing engine. This is substantially the plan now used in the Bessemer converter.

The first trial of this furnace was very satisfactory. The iron was well refined and decarbonized—at least as well as by the finery fire. This fact was admitted by all the forgemen who examined it. The blowing was usually continued from five to ten minutes, whereas the finery fire required over an hour. Here was a great saving of time and fuel, as well as great encouragement to work the process out to perfection. I was not satisfied with making refined or run-out metal; my object was to make malleable iron. In attempting this I made, in the course of the following eighteen months, a variety of experiments. I built a suitable hot-blast oven; but, after a few trials, abandoned it, finding the cold-blast preferable, for many reasons. After numerous trials of this furnace I found that I could make refined metal, suitable for the charcoal forge fire, without any difficulty, and, when the blast was continued for a longer period, the iron would occasionally be somewhat malleable. At one time, on trying the iron, to my great surprise, I found the iron would forge well, and it was pronounced as good as any charcoal forge iron. I had a piece of this iron forged into a bar four feet long and three-eighths of an inch square. I kept this bar for exhibition, and was frequently asked for a small piece, which I readily gave until it was reduced to a length of a few inches. This piece I have still in my possession. It is the first piece of malleable iron or steel ever made by the pneumatic process. The variability of results in the working of my experimental furnace was then a mystery which is now explained. An analysis having since been made of all the ore deposits of Suwannee furnace, they were found to embrace cold-short, red-short, and neutral ores. Some of the deposits showed a large percentage of manganese.

I now decided that, if I could not succeed in making malleable iron, I could turn my invention to practical account by putting up a furnace of sufficient capacity to supply our forge with refined or run-out metal, and at the same time continue my experiments as before. The difficulty here was in my blast. The furnace engine, though large and powerful, would not give over 5 pounds' pressure to the square inch. To overcome this difficulty I built a converting vessel and placed it in the pig-bed convenient to the tapping-hole of the hearth. This furnace was circular, built of boiler-plate iron, was about 5 feet high and 18 inches inside diameter; and, instead of blowing up through the bottom, the blast was applied to the sides, above the bottom, through four three-quarter-inch tuyeres. Experience soon proved that a single tuyere, an inch in diameter, answered my purpose best. In this vessel I could refine fifteen hundredweight of metal in from five to ten minutes. Should the blast prove weak, as was often the case, the tuyeres could be snuffed in the same way as in a finery fire. In this way a heavy charge could be worked with a weak blast. This furnace had an opening in the side, about nine inches square, three feet from the bottom, to run in the metal; also a tap-hole to let out the metal into a set of iron molds such as are used about finery fires. This furnace was found to answer a valuable purpose, supplying a cheap method of making run-out metal, and, after trying it a few days, we entirely dispensed with the old and troublesome run-out fires.

Our blooms were in high repute, and were almost entirely used for making boiler plates, so that many steamboats on the Ohio and Mississippi rivers were using boilers made of iron treated by this process some years before it was brought out in England. My process was known to every ironmaker in the Cumberland river iron district as "Kelly's air-boiling process." The reason why I did not apply for a patent for it sooner than I did was that I flattered myself I would soon make it the successful process I at first endeavored to achieve, namely, a process for making malleable iron and steel. In 1857 I applied for a patent, as soon as I heard that other men were following the same line of experiments in England; and, although Mr. Bessemer was a few days before me in obtaining a patent, I was granted an interference, and the case was heard by the commissioner of patents, who decided that I was the first inventor of this process, now known as the Bessemer process, and a patent was granted me over Mr. Bessemer.

It will be seen that Mr. Kelly claims for himself the discovery of the pneumatic principle of the Bessemer process several years before it dawned upon the mind of Mr. Bessemer. The validity of this claim cannot be impeached. But it must also be said that Mr. Bessemer successfully employed this principle in the production of steel, and that Mr. Kelly did not. The Kelly process produced only refined iron of good quality. Furthermore, the machinery with which Mr. Kelly operated his process was not calculated to produce rapidly or at all large masses of even refined iron; whereas Mr. Bessemer's machinery was successful almost from the first experiments that were made with it in producing steel in large quantities and with great rapidity.

Mr. Kelly claimed that his process, if successful in connection with the limited operations of the refinery forge attached to his blast furnace at Eddyville, would be applicable also to the refining of iron for rolling mills, and would take the place of puddling. Some experiments with this end in view were made at the Cambria iron works, at Johnstown, Pennsylvania, in 1857 and 1858, in a converting vessel similar to that now used in the Bessemer process. They were so far successful that Mr. Kelly wrote from Johnstown on the 29th of June, 1858, that he had not "the slightest difficulty in converting crude pig iron into refined plate metal by blowing into it for about fifteen to twenty-five minutes." These experiments were not, however, continued. Mr. Robert W. Hunt says that at Johnstown Mr. Kelly "met with the usual number of encouraging failures."

In May, 1863, Captain E. B. Ward, of Detroit, Daniel J. Morrell, of Johnstown, William M. Lyon and James Park, Jr., of Pittsburgh, and Z. S. Durfee, of New Bedford, Massachusetts, having obtained control of the original patent and other patents of Mr. Kelly, organized the Kelly Process Company, Mr. Kelly retaining an interest in any profits which might accrue to the company. The company resolved to establish experimental works, and also to acquire the patent in this country of Mr. Mushet for the use of *spiegeleisen* as a recarbonizing agent, through which the Bessemer process had been made a success in England. This patent was granted to Mr. Mushet in 1856 in England and in 1857 in this country. Experimental works were accordingly established at Wyandotte, Michigan, and Mr. Durfee was sent to England to procure an assignment of Mr. Mushet's patent. The latter purpose was effected on the 24th of October, 1864, upon terms which admitted Mr. Mushet, Thomas D. Clare, and John N. Brown, of England, to membership in the Kelly Process Company. On the 5th of September, 1865, the company was further enlarged by the admission to membership of Charles P. Chouteau, James Harrison, and Felix Vallé, all of Saint Louis. The works at Wyandotte were erected and operated under the superintendence of William F. Durfee, a cousin of Z. S. Durfee. In the fall of 1864 William F. Durfee succeeded in making Bessemer steel at the experimental works at Wyandotte, and this was the first Bessemer steel made in America. The machinery used at the Wyandotte works was certainly an infringement upon so much of Mr. Bessemer's patents as covered the machinery of his process.

The control in this country of Mr. Bessemer's patents was obtained in 1864 by John F. Winslow, John A. Griswold, and Alexander L. Holley, all of Troy, New York, Mr. Holley visiting England in 1863 in the interest of himself and his associates. In February, 1865, Mr. Holley was successful at Troy in producing Bessemer steel at experimental works which he had constructed at that place in 1864 for his company. Mr. Mushet's method of recarbonizing the iron in the converter was used at Troy, and this was an infringement of his patent.

As the Kelly Process Company could not achieve success without Mr. Bessemer's machinery, and as the owners of the right to use this machinery could not make steel without Mr. Mushet's improvement, an arrangement was effected by which all of the American patents were consolidated early in 1866. Under this arrangement the titles to the Kelly, Bessemer, and Mushet patents were vested in Messrs. Winslow, Griswold, and Morrell, the first two being owners of two-thirds of the property, and Mr. Morrell holding the other third in trust for the members of the Kelly Process Company. This arrangement continued until the formation of the Pneumatic Steel Association, a joint-stock company organized under the laws of New York, in which the ownership of the consolidated patents was continued. Z. S. Durfee acted as the secretary and treasurer of the company. The ownership of the patents is now vested in the Bessemer Steel Company Limited, an association organized under the laws of Pennsylvania. This company also owns all other patents in this country which relate in any way to the manufacture of Bessemer steel.

The consolidation, in 1866, of the various interests above mentioned was followed by a large reduction in fees and royalties, and thenceforward the business of making Bessemer steel was rapidly extended in this country. The order in which the various Bessemer steel works of the United States have been established is presented below.

1. Kelly Pneumatic Process Company, Wyandotte, Wayne county, Michigan. One 2½-ton experimental converter. Made its first blow in the fall of 1864. Bought by Captain E. B. Ward in 1865, and abandoned in 1869. These experimental works were connected with an iron rolling mill.

2. Albany and Rensselaer Iron and Steel Company, Troy, New York. Experimental Bessemer plant established by Winslow, Griswold & Holley. One 2½-ton converter. Made its first blow February 16, 1865. Now, two 6½-ton converters. Added to an iron rail mill.

3. Pennsylvania Steel Works, Pennsylvania Steel Company, Steelton post-office, Dauphin county, Pennsylvania. Two 6½-ton converters. Made their first blow in June, 1867. An entirely new works. Added three more converters in 1881.

4. Freedom Iron and Steel Works, Lewistown, Mifflin county, Pennsylvania. Two 5-ton converters. Made their first blow May 1, 1868. Added to the forge and blast furnaces of the Freedom Iron Company. Failed in 1869 and Bessemer works dismantled; most of the machinery went to Joliet, Illinois.

5. Cleveland Rolling Mill Company, Cleveland, Ohio. Two 6½-ton converters. Made their first blow October 15, 1868. Added to an iron rail mill.

6. Cambria Iron and Steel Works, Cambria Iron Company, Johnstown, Pennsylvania. Two 6-ton converters. Made their first blow July 10, 1871. Added to an iron rail mill.

7. Union Iron and Steel Company, Chicago, Illinois. Two 5½-ton converters. Made their first blow July 26, 1871. Added to an iron rail mill.

8. North Chicago Rolling Mill Company, Chicago, Illinois. Two 6½-ton converters. Made their first blow April 10, 1872. Added to an iron rail mill. Building two 10-ton converters and a complete rolling plant at South Chicago in 1881.

9. Joliet Steel Works, Joliet Steel Company, Joliet, Illinois. Two 5½-ton converters. Made their first blow January 26, 1873, and their first steel rail March 13, 1873. An entirely new works.

10. Bethlehem Iron Company, Bethlehem, Pennsylvania. Now four 7-ton converters; originally two 7-ton converters. Made their first blow October 4, 1873, and their first steel rail October 18, 1873. Added to an iron rail mill.

11. Edgar Thomson Steel Works, Carnegie Brothers & Company Limited, Bessemer station, Allegheny county, Pennsylvania. Two 7-ton converters. Made their first blow August 26, 1875, and their first steel rail September 1, 1875. An entirely new works. Adding one more converter in 1881.

12. Lackawanna Iron and Steel Works, Lackawanna Iron and Coal Company, Scranton, Lackawanna county, Pennsylvania. Two 7½-ton converters. Made their first blow October 23, 1875, and their first steel rail December 29, 1875. Added to an iron rail mill.

13. Vulcan Steel Company, St. Louis, Missouri. Two 6½-ton converters. Made their first blow September 1, 1876. Added to an iron rail mill.

14. Pittsburgh Bessemer Steel Company Limited, Homestead, Allegheny county, Pennsylvania. Two 4-ton converters. Made their first blow March 19, 1881. An entirely new works.

15. Pittsburgh Steel Casting Company, Pittsburgh, Pennsylvania. One 7-ton converter. Made its first blow August 26, 1881. Added to a crucible steel works. Product, ingots for special purposes; works not intended for the production of rails.

16. Colorado Coal and Iron Company, South Pueblo, Pueblo county, Colorado. Building two 5-ton converters in 1881. An entirely new works.

17. Scranton Steel Company, Scranton, Lackawanna county, Pennsylvania. Bessemer steel works projected and commenced in 1881. An entirely new works. To contain two 4-ton converters.

A summary of the above details shows that fifteen Bessemer works have been built in this country, of which two have been abandoned and thirteen are yet active, and that two additional Bessemer establishments are being built in 1881. The thirteen works that are now in operation employ thirty converters and will soon use three more. The works that are being constructed at South Pueblo and Scranton will add four more converters.

Mr. Robert W. Hunt informs us, in his *History of the Bessemer Manufacture in America*, read before the American Institute of Mining Engineers in 1876, that the first conversion made at Troy was from Crown Point charcoal pig iron, and that the first at Wyandotte was from Lake Superior charcoal pig iron.

Although Bessemer steel is adapted to all purposes for which other steel is used, except perhaps the manufacture of fine cutlery, its use in Europe has been mainly confined to the production of railway bars, and its use in this country has been even more narrowly limited to the same product. For many years after the introduction of the Bessemer process into the United States it was used to produce nothing but rails. The first Bessemer steel rails ever made in this country were rolled at the North Chicago rolling mill on the 24th of May, 1865, from hammered blooms made at the Wyandotte rolling mill from steel ingots made at the experimental steel works at Wyandotte. The rolls upon which the blooms were rolled at the North Chicago rolling mill had been in use for rolling iron rails. The steel rails came out sound and well-shaped. Several of these rails were laid in the track of one of the railroads running out of Chicago, and were still in use in 1875. The first steel rails rolled in the United States upon order, in the way of regular business, were rolled by the Cambria Iron Company, at Johnstown, Pennsylvania, in August, 1867, from ingots made at the works of the Pennsylvania Steel Company, near Harrisburg, Pennsylvania; and by the Spuyten Duyvil Rolling Mill Company, at Spuyten Duyvil, New York, early in September of that year, from ingots made at the Bessemer steel works at Troy, New York, then owned by Winslow & Griswold.

Important improvements upon Mr. Bessemer's machinery have been invented and patented by A. L. Holley, George Fritz, Robert W. Hunt, William R. Jones, and other American engineers. The inventive genius and rare mechanical skill of John Fritz have also produced many valuable improvements which were clearly patentable but have not been patented. In the early stages of the industry in this country great difficulty was experienced in obtaining suitable pig metal, and also materials for the lining of the converters. The lack of experienced workmen was also severely felt. All difficulties, however, have long been overcome. It is now universally admitted that in the United States the Bessemer steel industry has been brought to a higher state of perfection than it has attained in any other country. The American Bessemer works have been constructed after plans which are greatly superior to those of most European works.

The most recent improvement upon the Bessemer process is the work of two English chemists—Sidney Gilchrist Thomas and Percy C. Gilchrist, both of London. It renders possible the use in the converter of cast iron which contains a large percentage of phosphorus, no method of eliminating from it this hostile element having previously been in use. The first patent of Mr. Thomas, the principal inventor of this successful method of dephosphorizing iron, is dated November 22, 1877, and relates to the application of a basic lining to Bessemer converters. The Thomas-Gilchrist process is now practiced with success in Great Britain, France, Germany, Austria, Belgium, and Russia. It has not yet been introduced in this country. The entire control in the United States of the Thomas-Gilchrist patents has been purchased by the Bessemer Steel Company Limited. Jacob Reese, of Pittsburgh, claims priority of invention over Messrs. Thomas and Gilchrist.

Mr. Mushet's English patent for the use of *spiegeleisen* as a recarbonizer was permitted to lapse through causes over which he had no control, and before he had received any pecuniary benefit from his invention. Mr. Bessemer has, however, since partly recognized his indebtedness to Mr. Mushet's invention by allowing him an annuity of £300. Mr. Bessemer's own profits from his invention have been enormous. Mr. Jeans says that "from first to last Bessemer's patents have brought him royalties to the value of over £1,057,000." This statement was made in 1879. Mr. Jeans also gives some interesting particulars concerning the profits of the first company that was organized in England to work the Bessemer process. Mr. Bessemer was the projector of this company and a member of it, his associates being Messrs. Longsdon, Allen, and the Galloways of Manchester. The works were located at Sheffield. Mr. Jeans' statement is as follows:

On the expiration of the fourteen years' term of partnership of this firm, the works, which had been greatly increased from time to time, entirely out of revenues, were sold by private contract for exactly twenty-four times the amount of the whole subscribed capital, notwithstanding that the firm had divided in profits during the partnership a sum equal to fifty-seven times the gross capital, so that by the mere commercial working of the process, apart from the patent, each of the five partners retired, after fourteen years, from the Sheffield works with eighty-one times the amount of his subscribed capital, or an average of nearly cent. per cent. every two months—a result probably unprecedented in the annals of commerce.

The American Iron and Steel Association has ascertained as follows the production of Bessemer steel rails in the United States since the commencement, in 1867, of their manufacture in this country as a commercial product.

Years.	Net tons.	Years.	Net tons.	Years.	Net tons.
1867	2,550	1872	94,070	1877	432,169
1868	7,225	1873	129,015	1878	550,398
1869	9,650	1874	144,944	1879	683,964
1870	34,000	1875	290,863	1880	954,460
1871	38,250	1876	412,461		

The total production of rails in these fourteen years was 3,784,019 net tons. Since 1872 the Association has annually ascertained the production of Bessemer steel ingots in the United States. It has been as follows:

Years.	Net tons.	Years.	Net tons.	Years.	Net tons.
1872	120,108	1875	375,517	1878	732,226
1873	170,652	1876	525,996	1879	928,972
1874	191,933	1877	560,587	1880	1,203,173

A comparison of the production of ingots and rails since 1872 will show approximately the quantity of Bessemer steel that has annually been used in miscellaneous forms. Virtually all of the Bessemer steel that has ever been produced in this country has been used at home; only an infinitesimal quantity has been exported.

John A. Griswold was born at Nassau, Rensselaer county, New York, on November 14, 1818, and died at Troy, New York, on October 31, 1872, aged almost 54 years. Z. S. Durfee was born at Fall River, Massachusetts, on April 22, 1831, and died at Providence, Rhode Island, on June 8, 1880, aged over 49 years.

THE MANUFACTURE OF OPEN-HEARTH STEEL IN THE UNITED STATES.

The open-hearth process for the manufacture of steel, of which the Siemens-Martin furnace is the most popular type, consists in melting pig iron in a large dish-shaped vessel, or reverberatory furnace, and afterwards decarbonizing it by adding wrought iron, steel scrap, or iron ore—a deficiency of carbon being supplied, as in the Bessemer process, by the application of *spiegeleisen* or ferro-manganese; the product is steel, containing any percentage of carbon that may be desired. The materials are melted by the union in the furnace of atmospheric air and combustible gases, affording an intense heat. All of the heat employed is obtained by the use of a regenerative gas furnace. The melted pig metal, previous to receiving the decarbonizing ingredients, is termed a "bath." The quantity of steel that may be made at one operation, or "heat," ranges from five to fifteen tons, according to the size of the furnace.

The open-hearth process, although capable of producing as large masses of steel as the Bessemer process, is much slower in its operation, but it possesses the advantage over its rival that the melted mixture may be indefinitely kept in a state of fusion until experiments with small portions determine the exact conditions necessary to produce a required quality of steel. Another point of difference may be mentioned. While the distinctive features of both the Bessemer and the open-hearth processes embrace strictly chemical operations on a large scale—no direct manipulation of the contents of the Bessemer converter or open-hearth furnace being necessary, the success of the former mainly rests upon the wonderful power and perfection of the machinery by which it is operated, and the success of the latter mainly rests upon the appliances for producing and storing up the gases used in producing combustion.

Both processes may be combined with already-existing iron rolling mills or crucible steel works, but the open-hearth process can be most economically added to such establishments, and this is one cause of its increasing popularity, although, as already intimated, its productive capabilities are much less than those of the Bessemer process. The open-hearth process is also especially adapted to the utilization of the scrap steel and rail ends which accumulate at Bessemer steel works, and very naturally, therefore, many open-hearth furnaces have been built in connection with these works, both in Europe and in the United States. Another use to which the open-hearth process is adapted is the remelting of worn-out steel rails for the production of either new steel rails or steel in other forms. A popular use of the open-hearth process in Europe and America is the production of steel plates for boilers. In Europe open-hearth steel is also coming largely into use as a substitute for iron in shipbuilding. Preparations are being made to use open-hearth steel for the latter purpose in this country.

The importance of the two processes which have been mentioned, and the extent of the revolution they have effected, may be inferred from the fact that they have unitedly increased the world's production of steel fifty-fold in the last twenty-five years.

Previous to 1856, the same year in which Mr. Bessemer obtained his most important patent, (February 12, 1856,) Dr. Charles William Siemens gave his attention, in conjunction with his brother, Frederick Siemens, both of whom were natives of Hanover, in Germany, but at the time were citizens of England and residents of London, to the construction of a gas furnace for the manufacture of iron, steel, glass, and other products which require a high and uniform heat. These gentlemen were in that year successful in perfecting the Siemens regenerative gas furnace, which has since been widely introduced in Europe and in this country, and without which no open-hearth steel is now made. The first patent in connection with this invention was granted in 1856 to Frederick Siemens alone.

As early as 1861 Dr. Siemens experimented with the regenerative furnace in the production of cast steel in a reverberatory furnace, or open-hearth, for which application of the regenerative furnace he obtained a patent. He subsequently encountered great practical difficulties in establishing his process of making steel, efforts to accomplish this result being made in 1862 at Tow Law, and in 1863 and 1864 at Barrow and Fourchambault—the last-named place being in France and the others in England.

In 1864 Messrs. Emile and Pierre Martin, of the Sireuil works, in France, with the assistance of Dr. Siemens, erected one of the Siemens regenerative gas furnaces to melt steel in an open-hearth, or reverberatory furnace, of their own construction. In this furnace they produced cast steel of good quality and various tempers, and at the Paris Exposition of 1867 their product secured for them a gold medal. The Messrs. Martin subsequently obtained patents for various inventions of their own which were applicable to the manufacture of steel by the Siemens regenerative furnace.

Dr. Siemens claims, in a letter which is now before us, that, both at Tow Law and Fourchambault, cast steel had been produced upon an open-hearth, which had been specially constructed by himself for that purpose, from pig metal, *spiegeleisen*, and scrap iron, previous to Messrs. Martin's connection with the process. The furnace at Tow Law was a small one, and several such furnaces were recently at work there in the manner originally designed by Dr. Siemens. In 1865 Dr. Siemens commenced the erection at Birmingham, in England, of steel works of his own, in which the regenerative furnace should be used in producing steel. These works, which were completed in 1867, have produced satisfactory results.

The Messrs. Martin devoted their efforts to the production of steel by the dissolution of wrought iron and steel scrap in a bath of pig metal, while the efforts of Dr. Siemens were more especially directed to the production of steel by the use of pig metal and iron ores—the latter either in the raw state or in a more or less reduced condition. The Siemens, or "pig and ore," process is the one that is now generally employed in Great Britain. The Siemens-Martin, or "pig and scrap," process is the one that is chiefly used on the Continent and in this country. The credit of introducing it into this country is due to Hon. Abram S. Hewitt, of New York, who was favorably impressed with it when visiting the Paris Exposition in 1867 as a commissioner of the United States. At his request Frederick J. Slade, his business associate, went to Sireuil to study the process in order to put it into practice in this country.

Dr. Siemens and the Messrs. Martin obtained patents in this country for the use of their respective processes for manufacturing steel, and Dr. Siemens also obtained American patents for the Siemens gas furnace.

On the 1st of December, 1862, Park, McCurdy & Co., of Pittsburgh, sent Lewis Powe, the manager of their copper mill, to England to study the manufacture of tin plates. While there he visited Birmingham, and saw a Siemens gas furnace and procured one of the Siemens pamphlets containing a full description of it. On his return home he called the attention of James Park, Jr., to the advantages of the furnace. Immediately after July 4, 1863, the erection of a Siemens gas furnace was commenced at the copper works. This furnace was erected for the purpose of melting and refining copper, and was completed on the 14th of August, 1863. It was constructed after the drawings contained in the Siemens pamphlet, and worked well. In the fall of 1863 Mr. Powe revisited England, and while there had an interview with Dr. Siemens. Soon afterwards the firm of Park, Brother & Co. built a Siemens furnace to heat steel, but it was not a success. In 1864 James B. Lyon & Co., of Pittsburgh, built a Siemens gas furnace for making glass. The enterprise, however, although mechanically successful, met with an accident which suddenly brought it to an end. This furnace was also constructed after published designs. The introduction into this country of the Siemens furnace by each of the above-named firms was accomplished in an irregular manner, without first obtaining licenses from Dr. Siemens.

The first Siemens gas furnace that was regularly introduced into this country for any purpose was built by John A. Griswold & Co., at Troy, New York, and was used as a heating furnace in their rolling mill, the license having been granted on the 18th of September, 1867. The next gas furnace that was regularly introduced was used as a heating furnace by the Nashua Iron and Steel Company, of New Hampshire, the license for which was granted on the 26th of September, 1867. The next furnace that was regularly introduced was built by Anderson & Woods, of Pittsburgh, for melting steel in pots, the license for which was dated in November, 1867. About 1869 the owners of the Lenox plate-glass works in Massachusetts also built a Siemens gas furnace. All of these furnaces gave satisfaction.

The first open-hearth furnace introduced into this country for the manufacture of steel by the Siemens-Martin process was built in 1868 by Cooper, Hewitt & Co., proprietors of the works of the New Jersey Steel and Iron Company, at Trenton, New Jersey. The building of this furnace was commenced in the spring of 1868, and in December of the same year it was put in operation.

The first successful application in this country of the Siemens regenerative gas furnace to the puddling of iron was under the direction of William F. Durfee, at the rolling mill of the American Silver Steel Company, at Bridgeport, Connecticut, in 1869. Prior to this event an unsuccessful attempt was made to accomplish the same result at the Eagle rolling mill of James Wood & Co., at Saw Mill run, near Pittsburgh.

The production of open-hearth steel ingots in the United States in the census year 1880 was 84,302 net tons, only 9,105 tons of which were converted into rails, the remainder being used for miscellaneous purposes. At the close of the census year 1880 there were thirty-seven open-hearth furnaces in the United States, of which two were in Illinois, one was in Kentucky, four were in Massachusetts, one was in New Hampshire, one was in New Jersey, ten were in Ohio, fourteen were in Pennsylvania, one was in Rhode Island, two were in Tennessee, and one was in Vermont.

During the calendar year 1880 the production of open-hearth steel ingots in this country was much larger than during the census year, being 112,953 net tons, which was a little more than double the production of 1879. Our open-hearth steel industry has suddenly assumed large proportions, and is already an important factor in supplying the domestic demand for steel for all purposes for which Bessemer steel and the ordinary qualities of crucible steel may be used. It is destined to be still further developed in the immediate future. In 1872 the production of open-hearth steel ingots in this country was only 3,000 net tons, and in 1873 it was only 3,500 tons. The following statistics, compiled by the American Iron and Steel Association, will show the production of ingots since 1873 in the districts of the country containing open-hearth steel works.

Districts.	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Net tons.	*Net tons.*	*Net tons.*	*Net tons.*	*Net tons.*	*Net tons.*	*Net tons.*
New England	5,300	3,010	6,085	6,652	8,228	14,660	20,560
New Jersey and Pennsylvania	1,700	4,240	7,547	7,771	12,231	19,575	50,736
Western and Southern states	....	1,800	7,858	10,608	15,667	22,055	41,657
Total	7,000	9,050	21,490	25,031	36,126	56,290	112,953

The Pernot furnace is a modification of the open-hearth process which has been introduced into the United States from France, but, while producing good steel, it is not likely to grow in favor because of the great trouble and expense which are necessary to keep it in working order. The Ponsard furnace is another modification, but it has not been experimented with in this country, and is not likely to be.

Experimental works were erected at Pittsburgh in 1877 by Park, Brother & Co., in conjunction with Miller, Metcalf & Parkin, for the manufacture of refined iron directly from the ore by a process invented by Dr. Siemens, and successfully tested by him at his experimental works at Towcester, England. The process embodies the application of the Siemens gas furnace. The experiment was abandoned in 1879, the results being unsatisfactory. The same process was subsequently successfully established at Tyrone Forges, in Pennsylvania, by Anderson &

Co., of Pittsburgh. In 1881 Robert J. Anderson and his associates, under the name of the Siemens-Anderson Steel Company, erected extensive works of the same character at Pittsburgh. This process, like many other processes for the manufacture of iron or steel directly from the ore, has its reputation yet to make.

MISCELLANEOUS FACTS OF INTEREST RELATING TO THE DEVELOPMENT OF THE AMERICAN IRON INDUSTRY.

It would far transcend the limits assigned to this report if all of the modern inventions connected with the manufacture of iron and steel in this country were to be made the subject of historical and statistical inquiry. The most important of these inventions, and the history of their introduction into our country, have been referred to in preceding chapters. Several subjects of less importance relating to the mechanical development of our iron and steel industries will now be noticed, with which notice this branch of our subject will be dismissed.

Since the introduction into this country of the hot-blast in connection with the manufacture of pig iron, which occurred in the decade between 1830 and 1840, many methods of heating the air have been in use. Probably the first practical application of the hot-blast in this country was by William Henry, the manager of Oxford furnace, in New Jersey, in 1834. The waste heat at the tymp passed over the surface of a nest of small cast-iron pipes, through which the blast was conveyed to the furnace. The temperature was raised to 250° Fahrenheit, and the product of the furnace was increased about 10 per cent. In 1835 a hot-blast oven, containing cast-iron arched pipes, was placed on the top of the stack by Mr. Henry, and heated by the flame from the tunnel-head. By this arrangement the temperature of the blast was raised to 500°. This innovation in American blast-furnace practice increased the product of Oxford furnace about 40 per cent., with a saving of about the same percentage of fuel. No better device for heating the blast was in use in this country until about 1840. Hot-blast ovens, supplied with cast-iron arched pipes, of various patterns, were in general use in subsequent years down to about 1861, when an improvement in the construction of the oven, but embodying no essential modification of the system, was introduced by Samuel Thomas and adopted at many furnaces. In 1867 or 1868 John Player, of England, introduced his iron hot-blast stove into the United States, which soon became popular, owing to the facilities which it afforded for increasing the heat of the blast. Mr. Player personally superintended the erection of the first of his stoves in this country. It was erected at the anthracite furnace of J. B. Moorhead & Co., at West Conshohocken, Montgomery county, Pennsylvania, and is still in use. Down to the introduction of the Player hot-blast, the ovens, or stoves, were generally placed at the tunnel-head; Mr. Player placed his stove on the ground.

It is due to the memory of John Player that the fact should here be plainly stated that the introduction of his stove was the means of greatly increasing the yield of American furnaces and decreasing the quantity of fuel used to the ton of pig iron. After its introduction the temperature of the blast was generally raised, even where the Thomas and other ovens were used, and ere long powerful blowing engines were more generally used and higher furnaces were built. Connellsville coke was found to work admirably as a fuel for blast furnaces in connection with a powerful blast and high temperature. Since 1868 cast-iron stoves of various patterns have been increased in size, and in this and other improvements their efficiency in raising the temperature of the blast has been greatly promoted.

The Whitwell fire-brick hot-blast stove, also an English invention, was first used in this country at Rising Fawn furnace, in Dade county, Georgia, on June 18, 1875. Its next application was at Cedar Point furnace, at Port Henry, in Essex county, New York, on August 12, 1875. The stoves at Cedar Point furnace were, however, built before those at Rising Fawn furnace. The first application of this stove in Pennsylvania was made as late as February, 1877, at Dunbar furnace, in Fayette county. The Rising Fawn and Dunbar furnaces used coke as fuel, while Cedar Point furnace used anthracite. The first set of Siemens-Cowper-Cochrane fire-brick hot-blast stoves erected in this country was erected at one of the Crown Point furnaces, in Essex county, New York, in 1877; but the first set of these stoves erected in America was erected at Londonderry, in Nova Scotia, by the Steel Company of Canada Limited, in 1876. The Siemens-Cowper-Cochrane stove is also an English invention. Both it and the Whitwell stove embody the regenerative principle in storing heat. The introduction of these stoves has greatly promoted the economic management of American blast furnaces and increased their yield, supplementing and in all respects rivaling the good work inaugurated when the Player stove was introduced.

In the twenty years between 1840 and 1860 the plan of conveying the escaping gases from the top of the blast furnace to the boilers and hot-blast ovens, or stoves, gradually came into general use as a substitute for independent fires or for the use of the flame at the tunnel-head. Its introduction was greatly promoted between 1842 and 1850 by the efforts of Mr. C. E. Detmold, a German engineer, then residing at New York, but recently residing at Paris, who had taken out a patent in this country as assignee of Achilles Christian Wilhelm von Faber du Faur, superintendent of the government iron works at Wasseralfingen, in Wurtemberg, Germany, who had invented a method of utilizing furnace gases in heating the blast. The first practical experiments made by this invention in utilizing furnace gases in the production of heat were made in 1836 and 1837 at Wasseralfingen.

Achilles Christian Wilhelm von Faber du Faur was born on December 2, 1786. He studied at Freiberg in 1808; was first assistant superintendent of the government iron works at Kœnigsbronn in 1810, and afterwards was superintendent for thirty-two years of the government iron works at Wasseralfingen. In 1843 he became a member of the Mining Council (*Bergrath*) at Stuttgart, but owing to ill health he was compelled to retire from active service in 1845. He died on March 22, 1855.

David Thomas, of Catasauqua, Pennsylvania, was the first person in the United States to fully realize the value of powerful blowing engines in the working of blast furnaces. About 1852 he introduced engines at his furnaces at Catasauqua which increased the pressure to double that which was then customary in England. The results were surprising. But many years elapsed before Mr. Thomas's example was generally followed in this country. Within the past few years, however, our superior blast-furnace practice has been mainly due to the use of blowing engines of great power. English ironmasters have only within the past year commenced to imitate the best American practice in this respect.

At the Siberian rolling mill of Rogers & Burchfield, at Leechburg, in Armstrong county, Pennsylvania, natural gas, taken from a well 1,200 feet deep, was first used as a fuel in the manufacture of iron. In the fall of 1874 it was announced that during the preceding six months the gas had furnished all the fuel required for puddling, heating, and making steam, not one bushel of coal having been used. Since 1874 natural gas for puddling has been successfully used at the same rolling mill at Leechburg; at the works of Spang, Chalfant & Co., and Graff, Bennett & Co., in Allegheny county, Pennsylvania; and at the rolling mill of the Kittanning Iron Company, at Kittanning, Pennsylvania. In each instance the gas used has been obtained from wells that were sunk for oil but were found to produce only gas. The method employed in using the gas at Kittanning in the summer of 1881 has been described as follows:

> The gas is brought from a well some three miles distant, in four-inch casing, and at the mill is distributed amongst eighteen boiling furnaces. The furnaces are the same as those in which coal is used. The gas enters the rear of the furnace in three small pipes, shaped at the end like a nozzle. There being quite a pressure, the gas enters with considerable force, and by means of dampers to regulate the draft an intense and uniform heat is obtained. After a heat the furnace is cooled and prepared for the next heat in the same manner as with coal. When the metal is in place the gas is turned on, and the operation of puddling is the same, with the exception that it is somewhat slower. Only one-half of the well's production of gas is in fact consumed by the eighteen furnaces here described. The puddlers like the gas very much, as it reduces their labor to some extent, and they say they can make better weight than with coal. The furnaces being free from sulphur, a better quality of iron is produced, and it brings a slightly advanced price in the market. These furnaces have been running all the time for some months past, and have used nothing but gas for fuel, which has proved satisfactory in every respect, and is found to be much cheaper than coal.

We have previously recorded the erection in 1817, at Plumsock, in Fayette county, Pennsylvania, of the first rolling mill in the United States for the production of bar iron. The first puddling in this country was also done at this rolling mill in the same year. It may seem strange to many of the present generation, who witness the number and magnitude of our iron and steel establishments, that such important processes as the puddling of pig iron and the rolling of bar iron should not have been introduced into the United States until sixty-five years ago, but we have been unable to locate their introduction at an earlier period. Careful inquiry fails to discover the existence in the United States of any rolling mill to roll bar iron and puddle pig iron prior to the enterprise at Plumsock in 1817. We have, however, obtained the curious information that a patent was granted to Clemens Rentgen, of Kimberton, in Chester county, Pennsylvania, as late as June 27, 1810, for a machine to roll iron in round shapes, proving that Cort's rolls had not then been introduced into the United States. The original patent of Mr. Rentgen has been shown to us by his descendant, Professor William H. Wahl, of Philadelphia. We learn from this gentleman that Mr. Rentgen, before obtaining the patent in 1810 for his method of rolling round iron, built an experimental set of rolls, which were replaced by a permanent set after the patent was granted, with which he rolled round iron as early as 1812 or 1813, some of which was for the Navy Department of the United States Government. It is not claimed that he used puddling furnaces or rolled bar iron.

Ralph Crooker, recently of the Bay State iron works, at Boston, the oldest rolling-mill superintendent in the United States, writes us that the first bar iron rolled in New England was rolled at the Boston iron works, on the mill-dam in Boston, in 1825, and that the first puddling done in New England was at Boston, on the mill-dam, by Lyman, Ralston & Co., in 1835.

Before the use of bituminous and anthracite coal became general in this country wood was sometimes used to puddle pig iron, as it is now used at some places in Sweden, and it was also used in the heating furnaces of rolling mills. From 1821 to 1825 the Fall River rolling mill, in Massachusetts, used wood in heating iron for nail plates. In 1848 pig iron was puddled with wood at Adirondack, in Essex county, New York. Prior to 1850 puddling with wood was done at Horatio Ames's works at Falls Village, in Connecticut. In 1858 the Hurricane rolling mill and nail works, on Pacolet river, 43 miles west of Yorkville, in South Carolina, used dry pine wood in its puddling and heating furnaces; and in the preceding year the Cherokee Ford rolling mill, on Broad river, in Union county, in the same state, used "splint" wood for the same purposes.

It has already been stated that the Catalan forge, for the manufacture of iron directly from the ore, is still in use in the United States, and it may here be added that in some of the southern states it is used in the simple and inexpensive form in which it appears to have been introduced into this country, and which is known among metallurgists as the German bloomary. But in the Champlain district of New York the Catalan forge, or German bloomary, has been greatly improved. The blast is heated, which was never done with the old Catalan forge, but most of the power is still supplied by a water-wheel. Charcoal is the only fuel used, and great care is taken in its manufacture, as well as in calcining the ore, which is of a pure quality. The bloom produced in this forge usually weighs from 300 to 400 pounds. From the bloom is obtained a billet of refined iron, which goes into consumption in the manufacture of crucible and open-hearth steel, iron wire, plate and sheet iron, etc. About one ton of billets is produced at each forge in twenty-four hours. The blooms and billets are hammered into shape by a trip-hammer. In the census year 1880 there were in the Champlain district 22 establishments for the manufacture of blooms, embracing 141 forge fires. They produced 31,580 net tons of blooms in the year named. Statistics obtained by the American Iron and Steel Association show that the production of Champlain blooms has increased from 23,666 net tons in 1875 to 34,351 tons in the calendar year 1880.

The beginning of the regular manufacture of Connellsville coke, which is especially celebrated for its excellence as a fuel for blast furnaces, is said by Dr. Frank Cowan to date from the summer of 1841, when William Turner, Sr., P. McCormick, and James Campbell employed John Taylor to erect two ovens for making coke on his farm lying on the Youghiogheny river, a few miles below Connellsville, in Pennsylvania. The ovens were built of the bee-hive pattern. After repeated failures a fair quality of coke was produced in the winter of 1841–'42. By the spring of 1842 enough coke had been made to load a coal boat 90 feet long. This boat was taken down the Youghiogheny, the Monongahela, and the Ohio to Cincinnati, where a purchaser was obtained for the coke after some difficulty. This purchaser was Mr. Greenwood, a wealthy foundryman, and the price paid was 6¼ cents a bushel, half cash and half old mill irons. Others embarked in the business of manufacturing coke in 1842, Mordecai Cochran and Richard Brookius among the number, both of whom were successful. In 1844 improved ovens were introduced by Colonel A. M. Hill, whose energy and success gave a great impetus to the coke business. In 1855 there were only 26 coke ovens at work on the Monongahela river, and in all western Pennsylvania there were probably not over a hundred; now their number may be counted by thousands, most of which are built upon improved models. To-day Connellsville coke is extensively used in the blast furnaces of many states, its use for this purpose extending to the Mississippi valley. Fully one-third of the annual production of pig iron in this country is made with this fuel. Its use as a furnace fuel properly dates from 1860, when it was first used in a furnace at Pittsburgh owned by Graff, Bennett & Co., and known as Clinton furnace. This was the first continuous and successful use of Connellsville coke in a blast furnace. This coke is free from sulphur, but contains more ash than the celebrated Durham coke of England. One hundred pounds of Connellsville coal will make 62½ pounds of coke.

The Phœnix wrought-iron column, which is now in general use in this country and in Europe in the construction of wrought-iron bridges, viaducts, depots, warehouses, and other structures, is the invention of the late Samuel J. Reeves, of Philadelphia, a member of the Phœnix Iron Company, of Phœnixville, Pennsylvania. The invention was patented on June 17, 1862.

Mr. Reeves died at Phœnixville on December 15, 1878, aged 60 years. For many years previous to his death he had been president of the American Iron and Steel Association and of the Phœnix Iron Company. He was a native of Bridgeton, New Jersey. We mention his name with the reverence due to a good man's memory.

Down to 1846, when John Griffen built a rolling mill at Norristown, Pennsylvania, for Moore & Hooven, steam boilers had never been put over puddling and heating furnaces in any country. In this mill all the steam that was needed for driving the mill was generated in boilers over the puddling and heating furnaces, no auxiliary boilers being used or needed, thus greatly economizing fuel. Mr. Griffen met with much opposition from observers while constructing the mill upon this plan, and many predictions were made by them that the new arrangement would be a failure. It was a great innovation on the practice then prevailing, but it was a complete success, and its general adoption has effected a saving in fuel to the iron manufacturers in this country of many millions of dollars. Mr. Griffen has been for many years the general superintendent of the Phœnix iron works, at Phœnixville.

THE EARLY HISTORY OF IRON RAILS IN THE UNITED STATES.

The influence of railroads upon the development of the iron and steel industries of the United States has been so great that we will be justified in presenting in this chapter some of the leading facts connected with the laying of the first rails upon American railroads and with the manufacture of the first American rails.

The first railroads in the United States were built to haul gravel, stone, anthracite coal, and other heavy materials, and were all short, the longest probably not exceeding a mile in length. Strictly speaking, they were tramroads and not railroads. One of these was built on Beacon Hill, in Boston, by Silas Whitney, in 1807; another by Thomas Leiper, in Delaware county, Pennsylvania, in 1809; and another at Bear Creek furnace, in Armstrong county, Pennsylvania, in 1818. The tracks of these roads were composed of wooden rails. Other short tramroads were built in various places early in this century, and were similarly constructed. In George W. Smith's notes on Wood's *Treatise on Railroads* (1832) it is stated that "in 1816 the first railroad on which self-acting inclined planes were erected was executed by Mr. Boggs, on the Kiskiminetas river," in western Pennsylvania. This road was used to convey bituminous coal to Mr. Boggs's salt works.

Prior to 1809 Oliver Evans, of Philadelphia, to whom more than to any other person the honor of inventing the locomotive is due, urged in repeated addresses to the public the construction of a passenger railroad from Philadelphia to New York, and in that year he unsuccessfully attempted to form a company for this purpose. In 1812 Colonel John Stevens, of Hoboken, New Jersey, published a pamphlet, recommending the building of a passenger railroad from Albany to Lake Erie, but his suggestions were not heeded.

On the 7th of April, 1823, the state of New York chartered the Delaware and Hudson Canal Company to construct a canal and railroad from the coal fields of Pennsylvania to the Hudson river at Rondout in New York. The canal was completed in 1828, but the railroad was not completed until 1829. It was 16 miles long, and extended from Honesdale to Carbondale. It was built to carry coal.

In 1826 the Quincy railroad, in Massachusetts, 4 miles long, including branches, was built by Gridley Bryant and Colonel T. H. Perkins, to haul granite blocks from the Quincy quarries to the port of Neponset. The rails of this road were made of wood, but strapped with iron plates 3 inches wide and ¼ of an inch thick. In 1827 the Mauch Chunk railroad, in Carbon county, Pennsylvania, 9 miles long, with 4 miles of sidings, was built to connect the coal mines of the Lehigh Coal and Navigation Company with the Lehigh river. Its rails were also made of wood and strapped with iron. Gordon, in his *Gazetteer of the State of Pennsylvania*, (1832,) says of this road: "The railway is of timber, about 20 feet long, 4 inches by 5, and set in cross-pieces made of cloven trees placed 3½ feet from each other and secured by wedges. The rail is shod on the upper and inner edge with a flat bar of iron 2¼ inches wide and ⅝ of an inch thick." Solomon W. Roberts says of the Mauch Chunk road: "It was laid mostly on the turnpike, and was a wooden track, with a gauge of 3 feet 7 inches, and the wooden rails were strapped with common merchant bar iron, the flat bars being about 1½ inches wide and ⅜ of an inch thick. The holes for the spikes were drilled by hand. Although a great deal of bar iron, of somewhat varying sizes, was bought for the purpose, the supply fell short, and, to prevent delay in opening the road, strips of hard wood were spiked down in place of iron on about a mile and a half or two miles of the road, as a temporary expedient."

Mr. Roberts relates that the Lehigh Coal and Navigation Company made a short section of experimental railroad at its foundry in Mauch Chunk in the summer of 1826. "The idea then was to make a road with rails and chairs of cast iron, like those in use at the coal mines in the North of England. After casting a good many rails, each about 4 feet long, the plan was given up on account of its being too expensive."

In 1826 the state of New York granted a charter for the construction of the Mohawk and Hudson railroad, for the carriage of freight and passengers, from Albany to Schenectady, a distance of 17 miles. Work on this road, however, was not commenced until August, 1830; it was opened for travel on September 12, 1831.

On February 28, 1827, the state of Maryland granted a charter for the construction of the Baltimore and Ohio railroad, which was the first railroad in the United States that was opened for the conveyance of passengers. Its construction was commenced on July 4, 1828,—the venerable Charles Carroll, of Carrollton, laying the corner-stone. In 1829 the track was finished to Vinegar Hill, a distance of about 7 miles, and "cars were put upon it for the accommodation of the officers and to gratify the curious by a ride." Mr. Poor, in his *Manual of the Railroads of the United States*, says that the road was opened for travel from Baltimore to Ellicott's Mills, a distance of 13 miles, on May 24, 1830. The Washington branch was opened from Relay to Bladensburg on July 20, and to Washington City on August 25, 1834.

The next passenger railroad which was undertaken in the United States was the Charleston and Hamburg railroad, in South Carolina, which was chartered on December 19, 1827. Six miles of the road were completed in 1829, but they were not opened to the public until December 6, 1830, when a locomotive was placed on the track. The road was completed in September, 1833, a distance of 135 miles. At that time it was the longest continuous line of railroad in the world. The Columbia branch was opened on November 1, 1840, and the Camden branch on June 26, 1848. We need not further note the beginning of early American railroads.

The rails used on the Charleston and Hamburg and the Mohawk and Hudson railroads were made of wood, with flat bar iron nailed upon their upper surface. A writer in Brown's *History of the First Locomotives in America* says that the track of the Baltimore and Ohio railroad consisted of cedar cross-pieces, and of string-pieces of yellow pine "from 12 to 24 feet long and 6 inches square, and slightly beveled on the top of the upper side, for the flange of the wheels, which at that time was on the outside. On these string-pieces iron rails were placed and securely nailed down with wrought-iron nails, 4 inches long. After several miles of this description of road had been made long granite slabs were substituted for the cedar cross-pieces and the yellow-pine stringers. Beyond Vinegar Hill these huge blocks of this solid material could be seen deposited along the track, and gangs of workmen engaged in the various operations of dressing, drilling, laying, and affixing the iron." Brown says that "iron strips were laid, for miles and miles, on stone curbs on the Baltimore and Ohio railroad." Appleton's *American Cyclopædia* says that the iron used was ½ and ⅝ of an inch thick and from 2½ to 4½ inches wide, and that the heads of the spikes which fastened it were countersunk in the iron.

Before the Baltimore and Ohio railroad had been finished to Point of Rocks in 1832 "wrought-iron rails of the English mode," says Brown, had been laid down on a part of the line. The company had found in practice that the strap rail would become loosened from the wooden stringer, and that the ends of it, called "snakes' heads," were frequently forced by the wheels through the bottom of the cars, to the jeopardy of the passengers. The English rail obviated this inconvenience and risk.

About the time when the Baltimore and Ohio railroad was finished to Point of Rocks various patterns of heavy rolled iron rails were in use in England. The first of these to be used was the fish-bellied rail, which was invented by John Birkinshaw, of the Bedlington iron works, and patented in October, 1820, and which fitted into a cast-iron chair. A thin wedge, or key, of wrought iron was driven between the inside of the chair and the rail, to keep the latter firmly in its place, and the operation of "driving keys" had to be repeated almost every day.

The Birkinshaw rail was used on the Stockton and Darlington railroad, in England, which was opened in September, 1825, and was the first railroad in the world that was opened for general freight traffic and passenger travel. The larger part of the Stockton and Darlington road, which was 37 miles long, was laid with rolled rails of this pattern, weighing 28 pounds to the yard; a small part of the line was laid with fish-bellied cast-iron rails. The Liverpool and Manchester railroad, which was opened in September, 1830, and which was the second railroad built in England for general business, used rails which were also of the Birkinshaw pattern. "The rails used were made of forged iron, in lengths of 15 feet each, and weighed 175 pounds each. At the distance of every 3 feet the rail rests on blocks of stone. Into each block two holes, 6 inches deep and 1 inch in diameter, are drilled; into these are driven oak plugs, and the cast-iron chairs into which the rails are fitted are spiked down to the plugs, forming a structure of great solidity."

The Clarence rail was an English improvement on the Birkinshaw rail; it also rested in a chair, but it did not have the fish-belly, its upper and lower surfaces being parallel to each other. Rails of the Clarence pattern were used upon the Allegheny Portage railroad in Pennsylvania, which was finished in 1833, and many of the stone blocks on which they were laid can yet be seen in its abandoned bed. The Columbia and Philadelphia railroad was opened on the 16th of April, 1834. On a small part of this road flat rails were laid, either directly on granite blocks or on wooden string-pieces, but on the larger part of it Clarence rails were laid on stone blocks. On the Boston and Lowell railroad, which was chartered in June, 1830, and completed in 1835, stone cross-ties were at first laid, some of which were in use as late as 1852. On one track of this road the fish-bellied Birkinshaw rail was used, and on the other track the H rail was laid. This rail, which rested in a chair, had a web, or flange, similar to that of the modern T rail. The H rail was laid upon the Washington branch of the Baltimore and Ohio railroad. It was 15 feet in length, weighed 40 pounds to the yard, and was laid on string-pieces of wood. Wooden cross-ties have been substituted for stone blocks on all American railroads.

The following extract from a New York newspaper, dated May 30, 1844, shows the risk to which travelers were subjected who journeyed on railroads the tracks of which were laid with flat rails.

RAILROAD CASUALTY.—The cars on the railroad a short distance east of Rome, New York, came in contact with a "snake head" on Saturday morning which threw several of the passenger cars and the mail car off the track. The crush was tremendous, and the cars were torn to splinters, though happily no lives were lost. Mr. Peter Van Wie was badly bruised, and some others slightly injured.

The flat rail which was first used on American railroads continued in use for many years, notwithstanding the difficulty experienced in keeping it in its place. At first the holes for the spikes were drilled by hand. The flat rails which were afterwards made were indented, or countersunk, at regular distances in their passage through the rolls. The center of the countersunk surface was then punched through for the admission of the spike. As late as 1837, when the Erie and Kalamazoo railroad was in course of construction from Toledo to Adrian, it was proposed to put down wooden rails, of oak studding 4 inches square, and to draw the cars by horses. But wiser counsels prevailed, and by great exertions sufficient funds were obtained to enable the management to iron the road with flat rails $\frac{5}{8}$ of an inch thick. Mr. Poor says: "It was not until 1850 that the longitudinal sill and the flat rail were entirely removed from the Utica and Schenectady railroad, the most important link in the New York Central line." Flat rails were in use on many other railroads in this country after 1860, and may yet be seen on some southern railroads.

Cast-iron rails were made in this country in small quantities during the early years of our railroad history, notwithstanding the unfavorable experiment in their use at Mauch Chunk which is noted by Mr. Roberts. Johnson, in his *Notes on the Use of Anthracite*, written in 1841, records a series of tests made in that year with rails for mine roads, cast in a foundry from pig iron made at the Pottsville furnace of William Lyman. These rails were 6 feet long and were of various weights. It is particularly stated of one rail which was tested that it was "intended to sustain locomotives." The rails were bulbous at both the top and bottom, like the double-headed, or H, rail now used in England, but they had at each end, for about 3 inches along the base, flanges for securing them to the cross-ties, which caused an end view of them to resemble that of a modern T rail.

Many years elapsed after the first railroad was built in this country before any other than flat iron rails were made in American rolling mills. Among the proposals to furnish heavy rails for the Columbia and Philadelphia railroad, received in May, 1831, there were none for American rails, and the whole quantity was purchased in England. It is necessary to explain here that previous to the passage of the tariff act of 1842 rails were admitted into this country virtually free of duty. On the passage of that act American capitalists began to think about making heavy rails.

Early in 1844 there were still no facilities in this country for the manufacture of heavy iron rails to supply the wants of the 4,185 miles of American railroad which existed at the beginning of that year, and of a few hundred additional miles which were then projected. In a memorial which was laid before Congress in that year Hon. John Tucker, the president of the Philadelphia and Reading Railroad Company, under date of May 4, 1844, made the following declaration.

Immediately on the line of the road are rich mines of iron ore. Last fall and winter it was generally known in that section of the state through which the road passes, as well as on other portions of it, that this company intended to lay a second track, and that about 8,300 tons of railroad iron was wanted. Public proposals were issued for all the materials required, except the iron. The iron was not included in these proposals for the simple reason that I knew that it could not be furnished in this country, but I had interviews with several of the largest ironmasters, and freely expressed my desire to contract for American railroad iron, provided it could be furnished at the time it was wanted. I received no proposition to deliver the rolled bars. I inclose a copy of a letter from one of the largest ironmongers in the state, offering cast-iron rails, which, I presume you are aware, have not answered any good purpose. I also inclose a copy of my answer, to which I have not received a reply. I unhesitatingly express my conviction that the railroad iron needed by this company could not have been obtained in this country, at the time they required it, at any price; and I am equally confident that there are no parties ready to contract to deliver such iron for a long time to come. This company was therefore compelled to import their iron.

The following is the correspondence referred to above concerning the proposition to make cast-iron rails for the Philadelphia and Reading Railroad Company.

PHILADELPHIA, *November* 7, 1843.

MR. TUCKER: DEAR SIR: Since my conversation with you, in relation to substituting cast-iron rails for your new track of rails which you contemplate laying soon, I have concluded to propose to you that I should cast eighteen bar-rails 15 feet long from the model in the Franklin Institute, as a sample of the strength and durability of rails made from cast iron. The price to be $30 per ton cash upon delivering at Broad street. With respect, yours, CLEMENT B. GRUBB.

Direct Lancaster, Pennsylvania.

OFFICE OF THE PHILADELPHIA AND READING RAILROAD COMPANY, PHILADELPHIA, *November* —, 1843.

CLEMENT B. GRUBB, Esq., *Lancaster:* DEAR SIR: I duly received your communication of the 7th instant. This company is not disposed to make any experiment with the cast-iron rails on their own account. But if you choose to send the eighteen bars they shall be laid on the road; and if, after a trial of six months, they are found to answer a good purpose the company will pay you $30 per ton for the rails. If they are not suitable for the road they will then be delivered to you, the company merely incurring the expense of laying down and taking up the rails. Your obedient servant, JOHN TUCKER, *President.*

No reply was received to this.

The 8,300 tons of rails which were wanted by Mr. Tucker, and which he was compelled to buy in England, were of the H pattern, then very popular. The rails weighed 60 pounds to the yard, and cost £5 10*s*. per ton.

In a letter dated May 22, 1844, which formed a part of the above-mentioned memorial to Congress, Joseph E. Bloomfield made the following statement.

There is no doubt of the fact that there are no establishments for the manufacture of railroad iron in Pennsylvania prepared to produce a moiety of the iron required for the railways actually commenced. Mr. Oakley, of Brooklyn, made a statement, that at the time was combated and denied, that he could furnish from one set of works 10,000 tons of railroad iron per annum. This is so palpably incorrect that it needs no refutation. There is no iron establishment of this kind in this country.

On the 24th of April, 1844, the Hon. Edward Joy Morris, of Pennsylvania, declared that "not a ton of T rail had yet been made in this country." He might have included all other heavy patterns.

In 1844 the manufacture of heavy iron rails in this country was commenced at the Mount Savage rolling mill, in Alleghany county, Maryland, erected in 1843 especially to roll these rails. The first rail rolled at the Mount Savage rolling mill, and in honor of which the Franklin Institute of Philadelphia struck a silver medal, was a U rail, known in Wales as the Evans patent, of the Dowlais iron works, at Merthyr Tydvil. It was intended to be laid on a wooden longitudinal sill, and was fastened to it by an iron wedge, keying under the sill, thus dispensing with outside fastenings. This rail weighed 42 pounds to the yard. About 500 tons of rails of this pattern were laid in 1844 on a part of the road then being built between Mount Savage and Cumberland, a distance of nine miles. Soon afterwards rails weighing 52 pounds to the yard were rolled at the Mount Savage rolling mill for the road leading from Fall River to Boston. The foregoing information was obtained by us from Henry Thomas Weld, of Mount Savage.

The Montour rolling mill, at Danville, Pennsylvania, was built in 1845 expressly to roll rails, and here were rolled in October of that year the first T rails made in the United States. The first T-rail rolls made in this country were made for the Montour Iron Company by Haywood & Snyder, proprietors of the Colliery iron works at Pottsville, the work being done at their branch establishment at Danville. The Boston iron works were started in January, 1824, to manufacture cut nails, hoops, and tack plates, but they subsequently rolled rails, and on the 6th of May, 1846, they rolled the first T rails in Massachusetts, Ralph Crooker being superintendent. In 1845 the rolling mill of Cooper & Hewitt was built at Trenton, New Jersey, to roll heavy rails, and on the 19th of June, 1846, their first T rail was rolled. About the 1st of September, 1846, the New England Iron Company, at Providence, Rhode Island, commenced to roll T rails. The first lot of these rails rolled by the company was delivered to the Providence and Worcester railroad on September 11, 1846. T rails were rolled in November, 1846, at Phœnixville, Pennsylvania; in the fall of the same year at the Great Western iron works at Brady's Bend, Pennsylvania, and at the Lackawanna iron works at Scranton, Pennsylvania; early in 1847 at the Bay State rolling mill, in Massachusetts, then owned by the Massachusetts Iron Company; in January, 1848, at the Rough-and-Ready rolling mill at Danville, Pennsylvania; and in the same year at Safe Harbor, Pennsylvania. All of the T rails made at the mills above mentioned were rolled with a base or flange similar to that of the present T rail. Some of them did not differ greatly from the H rail, and when laid rested, like it, in a chair. Indeed the H rail was sometimes called the T rail. A few other mills rolled heavy rails before 1850, but at the beginning of that year, owing to foreign competition, only two out of fifteen rail mills in the country were in operation.

From *A History of the Growth of the Steam Engine*, by Robert H. Thurston, we learn that the present T rail is an American invention. Professor Thurston says: "Robert L. Stevens, the president and engineer of the Camden and Amboy railroad, and a distinguished son of Colonel John Stevens, of Hoboken, was engaged, at the time of the opening of the Liverpool and Manchester railroad, in the construction of the Camden and Amboy railroad. It was here that the first of the now standard form of T rail was laid down. It was of malleable iron. It was designed by Mr. Stevens, and is known in the United States as the 'Stevens' rail. In Europe, where it was introduced some years afterwards, it is sometimes called the 'Vignoles' rail." Professor Thurston adds that a part of the track of the Camden and Amboy railroad at Bordentown was laid down and opened for business in 1831. We presume that T rails were laid on the whole line, which crossed the state of New Jersey.

Through the courtesy of Professor Thurston we have been furnished with the accompanying *fac-simile* of the call issued by Mr. Stevens in 1830 for proposals for supplying the Camden and Amboy railroad with T rails.

The sides of the rails rolled for Mr. Stevens were made straight, and without "the projections on the lower flange at every two feet" which were specified in his call. These projections were intended to serve the purposes of cast-iron chairs then in use, by giving a broad base to the rail at its connection with the cross-ties.

Mr. Francis B. Stevens, of Hoboken, New Jersey, a nephew of Robert L. Stevens, has supplied us in the following letter with additional information concerning the history of the T rail. His letter is valuable, and, in connection with the *fac-simile* of the original call for proposals which we have given, conclusively establishes the fact that the present T rail was the invention of his uncle, Robert L. Stevens.

HOBOKEN, NEW JERSEY, *May* 31, 1881.

DEAR SIR: In answer to your letter of the 27th instant I will say that I have always believed that Robert L. Stevens was the inventor of what is called the T rail, and also of the method of fastening it by spikes, and I have never known his right to the invention questioned.

The rail of the Liverpool and Manchester railroad, on its opening, in September, 1830, was of wrought iron, divided into fish-bellied sections, each section being supported by a cast-iron chair, to which it was secured by a wooden wedge. This form was derived from the old cast-iron fish-bellied tram rail, cast in single sections, each about 36 inches long. This wrought-iron rail was afterwards improved by making its bottom straight uniformly throughout its length.

Mr. Stevens's invention consisted in adding the broad flange on the bottom, with a base sufficient to carry the load, and shaped so that it could be secured to the wood below it by spikes with hooked heads; thus dispensing with the cast-iron chair, and making the rail and its fastening such as it now is in common use. In the year 1836 and frequently afterwards he spoke to me about his invention of this rail, and told me that in London, after unsuccessful applications elsewhere in England, shortly after the opening of the Liverpool and Manchester railroad, he had applied to Mr. Guest, a member of Parliament, who had large rolling mills in Wales, to take a contract to make his rail for the Camden and Amboy railroad, of which he was the chief engineer; that Mr. Guest wished to take the contract, but considered that it would be impracticable to roll the rail straight; that, finally, Mr. Guest agreed to go to Wales with him and make a trial; that great difficulty was at first experienced, as the rails coming from the rolls curled like snakes, and distorted in every imaginable way; that, by perseverance, the rail was finally successfully rolled; and that Mr. Guest took the contract. The Camden and Amboy railroad, laid with this rail, was opened October 9, 1832, two years after the opening of the Liverpool and Manchester railroad. Of this I was a witness.

This rail, long known as the old Camden and Amboy rail, differed but little, either in shape or proportions, from the T rail now in common use, but weighed only 36 pounds to the yard. For the next six or eight years after the opening of the Camden and Amboy railroad this rail was but little used here or abroad, nearly all the roads built in the United States using the flat iron bar, about $2\frac{1}{4}$ inches by $\frac{5}{8}$ inch, nailed to wooden rails, and the English continuing to use the chair and wedge.

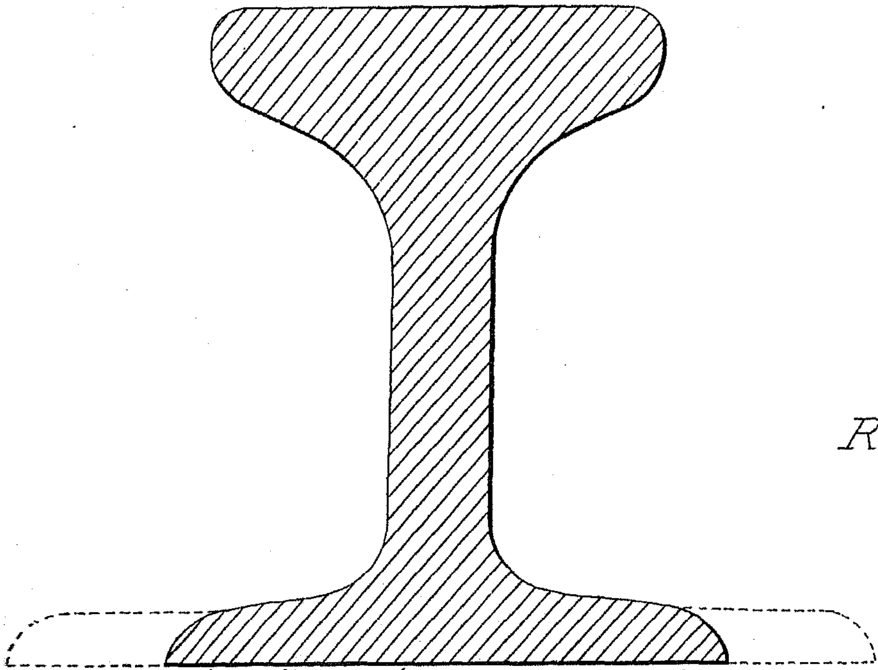
My uncle always regretted that he had not patented his invention. He mentioned to me, upwards of forty years ago, that when advised by his friend, Mr. F. B. Ogden, the American consul at Liverpool, who was familiar with the circumstances of his invention, to patent it, he found that it was too late, and that his invention had become public property. Yours, truly,

FRANCIS B. STEVENS.

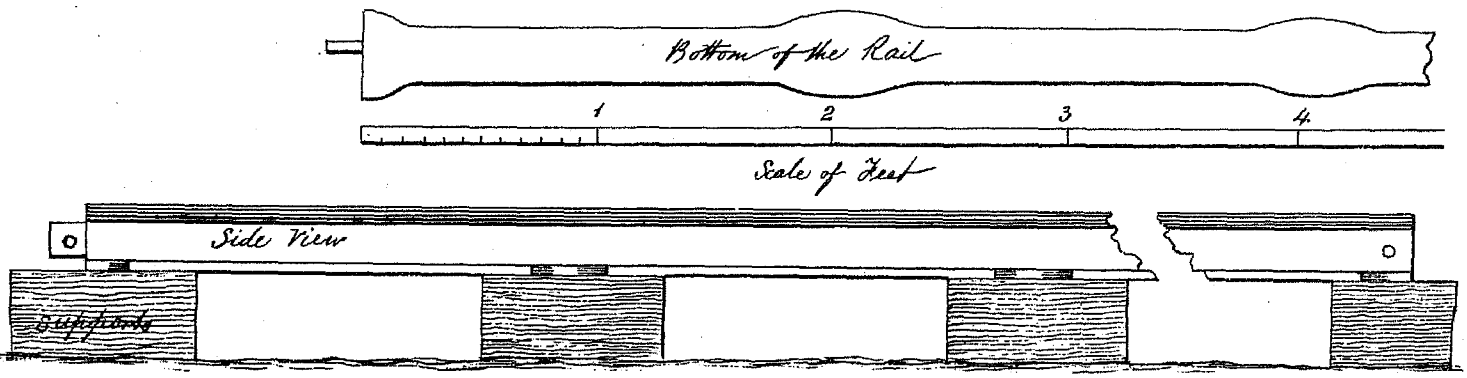
Smith, in his notes on Wood's *Treatise on Railroads*, thus describes the T rail which was laid on the Camden and Amboy railroad: "The rails are of rolled iron, 16 feet long, $2\frac{1}{8}$ inches wide on the top, $3\frac{1}{4}$ inches at the bottom, and $3\frac{1}{2}$ deep; the neck half inch thick; the weight is 209 pounds $= 39\frac{3}{16}$ pounds per yard; they are secured by clamps of iron, riveted at the extremity of each bar. The rails are attached to the stone blocks and sleepers by means of nails or pins, at the sides, driven into wooden plugs; chairs are dispensed with." It seems strange that the T rail should not have become generally popular in this country until after 1845.

The first 30-foot rail rolled in this country is claimed to have been rolled at the Cambria iron works at Johnstown, Pennsylvania, in 1855. These rails were perfectly made, but there being no demand for them they were used in the tracks of the Cambria Iron Company. It is claimed that the first 30-foot rails rolled in the country on order were rolled at the Montour rolling mill, in January, 1859, for the Sunbury and Erie Railroad Company. The first 60-foot, or double-length, rails rolled in this country were rolled by the Edgar Thomson Steel Company, at Braddock's Station, near Pittsburgh, Pennsylvania, in the fall of 1875. In 1877 the Lackawanna Iron and Coal Company, at Scranton, Pennsylvania, commenced to roll 60-foot rails. At the Centennial Exhibition at Philadelphia, in 1876, the Edgar Thomson Steel Company exhibited a steel rail which at that time was the longest steel rail that had ever been rolled. It was 120 feet long, and weighed 62 pounds to the yard.

Copy of the Call for Bids for T-rails issued by Robert L. Stevens in 1830.



Full size with projections at every two feet on the bottom flange, 3/4 of an inch by 4 inches.



Liverpool 1830.

Gentlemen

At what rate will you contract to deliver at Liverpool, say from five to six hundred tons of Railway, of the best quality Iron rolled to the above pattern in twelve or sixteen feet lengths, to lap as shewn in the drawing, with one hole at each end, and the projections on the lower flange at every two feet. Cash on delivery. How soon could you make the first delivery, and at what rate p month until the whole is complete. Should the terms suit and the work give satisfaction a more extended order is likely to follow, as this is but about one-sixth part of the quantity required. Please to address your answer (as soon as convenient) to the care of Francis B. Ogden, Consul of the United States at Liverpool

I am

Your obedient Servant

President & Engineer of the Camden & South Amboy Rail Road & transportation Company

The T rail is not much used in Great Britain. The pattern most in use in that country is the double-headed, or H, rail, which is set in a cast-iron chair. The bridge, or U, rail is in use on the Great Western railway and on some other railroads. The Clarence rail is still used on the Great Eastern railway, and perhaps on some other British railroads. In the United States the T rail is now almost exclusively used.

The first locomotive to run upon an American railroad was the *Stourbridge Lion*. It was first used on the coal railroad of the Delaware and Hudson Canal Company at Honesdale, in Susquehanna county, Pennsylvania, on Saturday, August 8, 1829. The *Stourbridge Lion* was built in England, and weighed about six tons. Its use was not long continued, because it was too heavy for the superstructure of a large part of the road. The first locomotive built in the United States and used on a railroad was the *Tom Thumb*, which was built by Peter Cooper at Baltimore, and successfully experimented with on the Baltimore and Ohio railroad in August, 1830. The fuel used for this pioneer American locomotive was anthracite coal. The boiler was tubular, and for want of specially-constructed tubes Mr. Cooper used gun barrels. The locomotive, which was also its own tender, did not weigh a ton. Strictly speaking, it was a working model, but it worked well and led the way to the construction of more powerful locomotives. Mr. Cooper was his own engineer. The first American locomotive that was built for actual service was the *Best Friend of Charleston*, which was built at the West Point foundry, in New York city, for the Charleston and Hamburg railroad, and was successfully put in use on that road in December, 1830. The Mohawk and Hudson railroad and a few other railroads used horse-power exclusively for some time after they were opened.

Mr. Brown informs us that "the first charter for what are termed city passenger or horse railroads was obtained in the city of New York and known as the New York and Harlem, and this was the first road of the kind ever constructed, and was opened in 1832. No other road of the kind was completed till 1852, when the Sixth Avenue was opened to the public."

The first elevated city passenger railway ever built was the Greenwich-street railway in New York, which was commenced in 1866 and has been in successful operation since 1872. The next project of this character was the Gilbert elevated railway, in New York, for the construction of which a charter was granted in 1872. The first elevated railroad constructed in this country in connection with a regular freight and passenger railroad was undertaken by the Pennsylvania Railroad Company in 1880 and finished in 1881. It constitutes an extension of the main line of the Pennsylvania railroad from West Philadelphia to the heart of the old city of Philadelphia, and is over a mile in length.

DIFFICULTIES ENCOUNTERED IN THE EARLY DEVELOPMENT OF THE AMERICAN IRON AND STEEL INDUSTRIES.

Many of the difficulties encountered in the early development of our iron and steel industries were inseparable from the conditions which attend the settlement of a new country, but others were of a political character, and grew out of the dependent relation of the colonies to Great Britain. Lord Sheffield declared that "the only use and advantage of American colonies or West India islands is the monopoly of their consumption and the carriage of their produce." McCulloch, in his *Commercial Dictionary*, admits that it was "a leading principle in the system of colonial policy, adopted as well by England as by the other European nations, to discourage all attempts to manufacture such articles in the colonies as could be provided for them by the mother country." Dr. Elder, in his *Questions of the Day*, says: "The colonies were held under restraint so absolute that, beyond the common domestic industries, and the most ordinary mechanical employments, no kind of manufactures was permitted." Bancroft, in his *History of the United States of America*, says that "England, in its relations with other states, sought a convenient tariff; in the colonies it prohibited industry." A law of Virginia, passed in 1684, to encourage textile manufactures in that province, was annulled in England. In 1699 the exportation, by land or water, of wool and woolen manufactures from one colony to another was prohibited. This was done that the English woolen manufacturers might have a monopoly in supplying the colonists with woolen goods. Other instances of special hostility to the establishment of manufactures in the colonies might be cited. The pages of Bancroft abound with them.

Concerning the attitude of Great Britain toward the woolen manufactures of the colonies, Adam Smith, in his *Wealth of Nations*, said in 1776: "She prohibits the exportation from one province to another by water, and even the carriage by land upon horseback or in a cart, of hats, of wools and woolen goods, of the produce of America; a regulation which effectually prevents the establishment of any manufacture of such commodities for distant sale, and confines the industry of her colonists in this way to such coarse and household manufactures as a private family commonly makes for its own use, or for that of some of its neighbors in the same province."

In the seventeenth century the colonial iron industry was so slowly developed that it attracted but little attention in the mother country; but at the beginning of the eighteenth century, when Pennsylvania, Maryland, and Virginia began to manufacture iron and to export it to England, the possibilities of its development in competition with the English iron industry became a terror to English ironmasters. In 1719 the House of Commons passed a bill containing the clause "that none in the plantations should manufacture iron wares of any kind out of any sows, pigs, or bars whatsoever." The House of Lords added, "that no forge, going by water, or other works, should be erected in any of the said plantations, for the making, working, or converting of any sows, pigs, or cast iron into bar or rod iron." "The opposition of the northern colonies defeated the bill," says Bancroft; "England would not yet forbid the colonists to manufacture a bolt or a nail; but the purpose was never abandoned."

The distinguished American historian records in the following language the culmination of the repressive policy of the mother country toward the iron industry of the colonies: "America abounded in iron ore; its unwrought iron was excluded by a duty from the English market; and its people were rapidly gaining skill at the furnace and the forge. In February, 1750, the subject engaged the attention of the House of Commons. To check the danger of American rivalry, Charles Townshend was placed at the head of a commission. . . . After a few days' deliberation he brought in a bill which permitted American iron in its rudest forms to be imported duty free; but, now that the nailers in the colonies could afford spikes and large nails cheaper than the English, it forbade the smiths of America to erect any mill for slitting or rolling iron, or any plating-forge to work with a tilt-hammer, or any furnace for making steel. . . . The House divided on the proposal that every slitting mill in America should be abolished. The clause failed only by a majority of twenty-two; but an immediate return was required of every mill already existing, and the number was never to be increased." The act of Parliament to which Bancroft here alludes contained many elaborate provisions, but its principal provisions were as follows:

WHEREAS, The Importation of Bar Iron from His Majesty's Colonies in America into the Port of London, and the Importation of Pig Iron from the said Colonies, into any Port of Great Britain, and the Manufacture of such Bar and Pig Iron in Great Britain, will be a great Advantage, not only to the said Colonies, but also to this Kingdom, by furnishing the Manufacturers of Iron with a supply of that useful and necessary Commodity, and by means thereof large sums of Money, now annually paid for Iron to Foreigners, will be saved to this Kingdom, and a greater quantity of the Woollen, and other Manufactures of Great Britain, will be exported to America, in Exchange for such Iron so imported; be it therefore enacted by the King's Most Excellent Majesty, by and with the advice and consent of the Lords, Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, That from and after the Twenty-fourth day of June, one thousand seven hundred and fifty, the several and respective Subsidies, Customs, Impositions, Rates, and Duties, now payable on Pig Iron, made in and imported from His Majesty's Colonies in America, into any Port of Great Britain, shall cease, determine, and be no longer paid; and that from and after the said Twenty-fourth day of June, no Subsidy, Custom, Imposition, Rate, or Duty whatever, shall be payable upon Bar Iron made in and imported from the said Colonies into the Port of London; any Law, Statute, or usage to the contrary thereof in any wise notwithstanding.

And, that Pig and Bar Iron made in His Majesty's Colonies in America may be further manufactured in this Kingdom, be it further enacted by the Authority aforesaid, That from and after the Twenty-fourth day of June, one thousand seven hundred and fifty, no Mill or other Engine for Slitting or Rolling of Iron, or any Plateing Forge to work with a Tilt Hammer, or any Furnace for making Steel, shall be erected, or after such Erection continued in any of His Majesty's Colonies in America; and if any Person or Persons shall erect, or cause to be erected, or after such Erection continue, or cause to be continued, in any of the said Colonies, any such Mill, Engine, Forge, or Furnace, every Person or Persons so offending shall, for every such Mill, Engine, Forge, or Furnace, forfeit the Sum of Two Hundred Pounds of lawful Money of Great Britain.

And it is hereby further enacted by the Authority aforesaid, That every such Mill, Engine, Forge, or Furnace, so erected or continued, contrary to the Directions of this Act, shall be deemed a Common Nuisance, and that every Governor, Lieutenant Governor, or Commander-in-Chief of any of His Majesty's Colonies in America, where any such Mill, Engine, Forge, or Furnace, shall be erected or continued, shall, upon Information to him made and given, upon the Oath of any Two or more Credible Witnesses, that any such Mill, Engine, Forge, or Furnace, hath been so erected or continued (which Oath such Governor, Lieutenant Governor, or Commander-in-Chief, is hereby authorized and required to administer) order and cause every such Mill, Engine, Forge, or Furnace, to be abated within the Space of Thirty Days next after such Information given and made as aforesaid.

The provision in the above act which repealed the duties on colonial pig iron and bar iron was wholly based on the necessities of the mother country, and was not in the least due to a desire to build up a colonial iron industry for the benefit of the colonies themselves. There was in 1750 a scarcity of timber in England for the supply of charcoal, which was then the principal fuel used in the smelting and refining of iron, but forests everywhere abounded in the colonies, and iron ore had been found in many places. The manufacture of pig iron and bar iron in the colonies, and their exportation to England, to meet a scarcity of the domestic supply of these products, and to be exchanged for British woolen and other manufactures, was therefore encouraged. The provision relating to articles made *from* pig iron and bar iron was intended to be prohibitory of their manufacture in the colonies. Adam Smith thus described in 1775 the character of this legislation, which had not been repealed nor altered down to that period, the beginning of our Revolution: "While Great Britain encourages in America the manufactures of pig and bar iron, by exempting them from duties to which the like commodities are subject when imported from any other country, she imposes an absolute prohibition upon the erection of steel furnaces and slit-mills in any of her American plantations. She will not suffer her colonists to work in those more refined manufactures even for their own consumption, but insists upon their purchasing of her merchants and manufacturers all goods of this kind which they have occasion for."

As may easily be imagined, the passage of this act aroused anew the feeling of discontent in the colonies which had been created and kept alive by many repressive measures of the mother country directed against their infant manufactures. These measures of repression formed the principal part of that "long train of abuses and usurpations" which led to the war of independence.

From the passage of the act of 1750 down to the Revolution our iron industry was mainly confined to the production of pig iron and bar iron. The effect of the act was to repress the development of our steel industry and of the finished branches of our iron industry. During this period we made pig iron and bar iron in sufficient quantities for our own use, and the surplus was sent to the mother country.

But the colonies suffered also from the general restrictive policy of Great Britain affecting the manufactures of all foreign countries. Adam Smith gives us the following view of this policy.

By the 7th and 8th of William III. [1696 and 1697], chapter 20, section 8, the exportation of frames or engines for knitting gloves or stockings is prohibited under the penalty not only of the forfeiture of such frames or engines so exported, or attempted to be exported, but of forty pounds—one-half to the king, the other to the person who shall inform or sue for the same.

By the 5th George I. [1718], chapter 27, the person who shall be convicted of enticing any artificer of, or in any of the manufactures of, Great Britain, to go into any foreign parts in order to practice or teach his trade, is liable, for the first offense, to be fined in any sum not exceeding one hundred pounds, and to three months' imprisonment, and until the fine shall be paid; and, for the second offense, to be fined in any sum at the discretion of the court, and to imprisonment for twelve months, and until the fine shall be paid. By the 23d George II. [1749], chapter 13, this penalty is increased, for the first offense, to five hundred pounds for every artificer so enticed, and to twelve months' imprisonment, and until the fine shall be paid; and, for the second offense, to one thousand pounds, and to two years' imprisonment, and until the fine shall be paid.

By the former of those two statutes, upon proof that any person has been enticing any artificer, or that any artificer has promised or contracted to go into foreign parts for the purposes aforesaid, such artificer may be obliged to give security at the discretion of the court that he shall not go beyond the seas, and may be committed to prison until he give such security.

If any artificer has gone beyond the seas, and is exercising or teaching his trade in any foreign country, upon warning being given to him by any of his majesty's ministers or consuls abroad, or by one of his majesty's secretaries of state for the time being, if he does not within six months after such warning return to this realm, and from thenceforth abide and inhabit continually within the same, he is from thenceforth declared incapable of taking any legacy devised to him within this kingdom, or of being executor or administrator to any person, or of taking any lands within this kingdom by descent, devise, or purchase. He likewise forfeits to the king all his lands, goods and chattels, is declared an alien in every respect, and is put out of the king's protection.

The policy which is epitomized above by the great English political economist was continued after the American colonies secured their independence. We copy below the leading provisions of an act of the British Parliament, adopted in 1781, the twenty-first year of the reign of George the Third, which prohibited the exportation from Great Britain of machinery used in the manufacture of cotton, linen, wool, and silk.

An Act to explain and amend an Act made in the fourteenth Year of the Reign of his present Majesty, intituled, *An Act to prevent the Exportation to foreign Parts of Utensils made use of in the Cotton, Linen, Woollen, and Silk Manufactures of this Kingdom* . . . That if, at any Time after the twenty-fourth Day of *June*, one thousand seven hundred and eighty-one, any Person or Persons in *Great Britain* or *Ireland* shall . . . put on Board of any Ship or Vessel, which shall not be bound directly to some Port or Place in *Great Britain* or *Ireland*, . . . any Machine, Engine, Tool, Press, Paper, Utensil, or Implement whatsoever, which now is, or at any Time or Times hereafter shall or may be used in, or proper for the preparing, working, pressing, finishing, or completing, of the Woollen, Cotton, Linen, or Silk Manufactures of this Kingdom . . . ; or any Model or Plan, or Models or Plans, of any such Machine, Engine, Tool, Press, Paper, Utensil, or Implement, or any Part or Parts thereof, . . . the Person or Persons so offending shall, for every such Offence, not only forfeit all such Machines, Engines, Tools, Press, Paper, Utensils, or Implements, Models or Plans, or Parts thereof respectively, together with the Packages, and all other Goods packed therewith, if any such there be, but also the Sum of two hundred Pounds of lawful Money of *Great Britain*; and shall also suffer Imprisonment . . . for the Space of twelve Months, without Bail or Mainprize, and until such Forfeiture shall be paid. . . . Provided always, That nothing herein contained shall extend to the preventing Wool Cards, or Stock Cards, not exceeding in Value four Shillings *per* Pair, and Spinners Cards not exceeding in Value one Shilling and Sixpence *per* Pair, used in the said Woollen Manufacture, from being exported to any of his Majesty's Colonies or Plantations in *America*.

In 1785, the twenty-fifth year of the reign of George the Third, an act was passed to cripple if possible the iron industries of foreign countries, the principal provisions of which were as follows:

An Act to prohibit the Exportation to foreign Parts of Tools and Utensils made use of in the Iron and Steel Manufactures of this Kingdom; and to prevent the seducing of Artificers or Workmen, employed in those Manufactures, to go into Parts beyond the Seas.

Whereas, the Exportation of the several Tools and Utensils made use of in preparing, working up, and finishing the Iron and Steel Manufactures of this Kingdom, or either of them, will enable Foreigners to work up such Manufactures, and thereby greatly diminish the Exportation of the same from this Kingdom; therefore, for the preserving, as much as possible, to his Majesty's Subjects the Benefits arising from those great and valuable Branches of Trade and Commerce, may it please your Majesty that it may be enacted, and be it enacted by the King's most Excellent Majesty, by and with the Advice and Consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the Authority of the same, That if, at any Time after the first Day of *August*, one thousand seven hundred and eighty-five, any Person or Persons in *Great Britain* shall, upon any Pretence whatsoever, export, load, or put on board, or pack, or cause or procure to be loaden, put on board, or packed, in order to be loaded or put on board of any Ship or Vessel which shall be bound to some Port or Place in Parts beyond the Seas (except to *Ireland*), or shall lade, or cause or procure to be laden, on Board any Boat or other Vessel, or shall bring, or cause to be brought, to any Quay, Wharf, or other Place, in order to be so laden or put on board any such Ship or Vessel, any Tool or Utensil hereafter mentioned; that is to say, Hand Stamps, Dog Head Stamps, Pulley Stamps, Stamps of all sorts, Hammers and Anvils for Stamps, Screws for Stamps, Iron Rods for Stamps, Presses of all Sorts, in Iron, Steel, or other Metal, which are used for giving Impressions to Metal, or any Parts of these several Articles; Presses of all Sorts called *Cutting-out Presses*, Beds and Punches to be used therewith; Piercing Presses of all Sorts, Beds and Punches to be used therewith, either in Parts or Pieces, or fitted together; Iron or Steel Dies to be used in Stamps or Presses either with or without Impressions on them; Rollers of Cast Iron, Wrought Iron, or Steel, for rolling of Metal, and Frames for the same; Flasks or Casting Moulds, and Boards used therewith; Lathes of all Sorts for turning, burnishing, polishing, either the Whole together, or separate Parts thereof; Lathe Strings, polishing Brushes, Scoring or Shading Engines, Presses for Horn Buttons, Dies for Horn Buttons, Sheers for cutting of Metal, Rolled Steel, Rolled Metal with Silver thereon, Parts of Buttons not fitted up into Buttons, or in an unfinished State; Engines for Chafing, Stocks for casting Buckles, Buttons, and Rings; Cast Iron Anvils and Hammers for Forging Mills for Iron and Copper; Roles, Slitters, Beds, Pillars and Frames for Slitting Mills; Die-sinking Tools of all Sorts, Engines for making Button Shanks, Laps of all Sorts, Drilling Engines, Tools for pinching of Glass, Engines for covering of Whips, Polishing Brushes, Bars of Metal covered with Gold or Silver, Iron or Steel Screw Plates, Pins, and Stocks for making Screws, or any other Tool or Utensil whatsoever, which now is, are, or at any Time or Times hereafter shall or may be used in, or proper for the preparing, working, finishing, or completing of the Iron or Steel Manufactures of this Kingdom, or either of them, by what Name or Names soever the same shall be called or known, or any Model or Plan, or Models or Plans, of any such Tool, Utensil, or Implement, or any Part or Parts thereof; the Person or Persons so offending shall for every such Offence, not only forfeit and lose all such Tools or Utensils, or Parts or Parcels thereof, together with the Packages, and all other Goods packed therewith, if any such there be, . . . the Person or Persons so offending shall, for every such Offence, forfeit the Sum of two hundred Pounds of lawful Money of *Great Britain*, and shall also suffer Imprisonment, in the Common Gaol, Prison, or House of Correction, . . . for the space of twelve Months, without Bail or Mainprize, and until such Forfeiture shall be paid.

And whereas, for the encouragement of such Manufactories in this Kingdom, it is necessary that Provision should be made to prevent Artificers, and others employed therein, from departing, or from being seduced to depart out of this Kingdom; be it therefore enacted by the Authority aforesaid, That from and after the said first day of August, one thousand seven hundred and eighty-five, if any Person or Persons shall contract with, entice, persuade, or endeavor to seduce or encourage any Artificer or Workman concerned or employed, or who shall have worked at, or been employed in, the Iron or Steel Manufactures in this Kingdom, or in making or preparing any Tools or Utensils for such Manufactory, to go out of Great Britain to any Parts beyond the Seas (except to Ireland), and shall be convicted thereof . . . shall, for every Artificer so contracted with, enticed, persuaded, encouraged, or seduced, or attempted so to be, forfeit and pay the Sum of five hundred Pounds of lawful Money of Great Britain, and shall be committed to the Common Gaol, . . . there to remain without Bail or Mainprize for the Space of twelve Calendar Months, and until such Forfeiture shall be paid; and in Case of a subsequent Offence of the same Kind, the Person or Persons so again offending shall, upon the like Conviction, forfeit and pay, for every Person so contracted with, enticed, persuaded, encouraged, or seduced, or attempted so to be, the Sum of one thousand Pounds of lawful Money of Great Britain, and shall be committed to the Common Gaol as aforesaid, there to remain, without Bail or Mainprize, for and during the Term of two Years, and until such Forfeitures shall be paid.

In 1786 some trifling changes were made in the list of articles the exportation of which was prohibited, but the principal articles used in the manufacture of iron and steel were carefully preserved in the list. At the same time tools for making paper, for making and working glass, and for making pottery and harness were added to the list. In 1799 an act was passed providing that,

Whereas, there have of late been many attempts to seduce colliers out of Scotland into foreign countries, be it therefore further enacted that all persons seducing, or attempting to seduce, colliers . . . from the Kingdom of Great Britain shall be punished in the same manner as persons seducing, or attempting to seduce, manufacturers or other artisans are punishable by law.

The prohibition of the exportation of machinery for the manufacture of iron and steel, and other machinery, continued until after the beginning of the present century. Machinery for the manufacture of linen was not permitted to be exported until 1842. The statutes interfering with the emigration of artificers were not wholly repealed until 1825.

During our Revolution and immediately after its close the iron industry of Great Britain was greatly stimulated by the general substitution of bituminous coal for charcoal, by the application of the steam engine to the blowing of furnaces, and by the introduction of the puddling furnace and grooved rolls in the refining and finishing of iron. These improvements greatly increased and cheapened the iron products of Great Britain, so that, instead of being dependent upon this country for a supply of pig iron and bar iron, she was enabled to send these and other iron products to her former colonies in successful competition with their manufactures. The effect was to greatly retard the extension of our iron industry after the Revolution. The competition which produced this result might have been averted if the emancipated colonies had followed the example of the mother country and imposed duties upon foreign iron and steel that would have protected the domestic manufacture of these products. Under the Articles of Confederation and for many years after the establishment of our "more perfect union" duties upon foreign imports of every description were so low that they afforded no adequate protection to American manufactures. From 1789 to 1812 the duty on pig iron and bar iron ranged from 5 per cent. to 19½ per cent. of their value. In the same years the duty on steel ranged from 50 cents to $1.10 per cwt.

The following petition, presented to the General Assembly of Pennsylvania on November 30, 1785, two years before the adoption of the Federal Constitution, shows the effect at that time of foreign competition upon the manufacture of bar iron in Pennsylvania.

To the Honorable the Representatives of the Freemen of the Commonwealth of Pennsylvania in General Assembly met.

The Petition of the Subscribers, Manufacturers of Bar Iron within the Commonwealth aforesaid, respectfully sheweth

That, by an Act passed during the last Session of the late Assembly, additional Duties are laid on the Importation of divers Manufactures of Europe and other foreign Parts, for the Purpose of protecting and encouraging the Manufactures of this State, wherein your Petitioners find the Article of Bar Iron has been omitted.

That the manufacturing of Bar Iron within this State has not only been found very Useful and important during the late War, but has always been considered as a Source of public Wealth and Benefit; as great Sums of Money were thereby kept within the Country; which circulating through the Hands of several Thousand Persons, employed in the Manufactures of Bar Iron and furnishing the requisite Materials, enabled them to maintain themselves and their Families and contribute to the Support of Government by Payment of Taxes—and an Influx of Specie and other considerable Advantages were also derived to the Trade of this State by the Exportation of great Quantities of Bar Iron to other Parts of the Continent.

That, although most of the Iron manufactured within this State is confessedly superior in Quality to the Iron imported from foreign Parts, yet, because Iron can not be manufactured at so low a Price here as in Countries where the Labourers are but little removed above the Condition of Slaves, the Sale of divers large Quantities of foreign Iron lately imported into this State, notwithstanding its inferior Quality, operates so much to the Prejudice of all Persons concerned in the Manufacture of Bar Iron here, that there is great Reason to apprehend, unless the Legislature shall extend their Aid, further Importations of foreign Iron will in a short Time occasion a total Stoppage and Destruction of that very useful and beneficial Manufacture amongst us.

Your Petitioners trust that, on full Consideration of the Premises, the Manufacture of Bar Iron within this State will appear to your Honorable House essentially entitled to public Protection and Encouragement, and therefore pray your Honorable House may be pleased to grant Relief in the Premises by laying such Additional Duties on foreign Bar Iron as will prevent further Importations thereof becoming destructive or oppressive to the Manufacture of Bar Iron within this State.

And your Petitioners as in Duty bound shall ever pray, &c.

JACOB MORGAN, JR.	SAML. POTTS.	CURTTIS GRUBB.	WILLIAM BIRD.
DAVID POTTS.	J. HOCKLEY.	PETER GRUBB, SR.	JACOB LESHET.
JAMES HARTLEY.	WM. HAYES.	ROBT. COLEMAN.	MICHL. EGE.
ANDW. PETTIT.	JOHN PATTON.	MATTHIAS HOUGH.	JN. HELLINGS.
JESSE GRUNFIELD.	GEORGE EGE.	WILLIAM OLDE.	ABRM. SHARPLES.
THOS. HUMPHREYS.	JACOB WINEY.	DAVID JENKINS.	HILARY BAKER.
THOS. RUTTER.	VALENTINE ECKERT.	JAMES OLD.	C. DOUGLASS.
THOS. MAYBURRY.	PETER GRUBB, JR.	JNO. EDWARDS.	RICHD. BACKHOUSE.

The petition was referred on the day of its presentation to a committee composed of Mr. Fitzimmons, Mr. Clymer, and Mr. Whitehill, who submitted an adverse report on the 7th of December, as follows: "That with respect to bar iron it appears that a sufficient quantity may be made in the state, not only for its particular use, but a large overplus for exportation, but that, by the large importations lately made, the price is so much reduced as to disable the owners of forges to go on with their business. Your committee, however, viewing bar iron as necessary to the agriculture and manufactures of the state, are doubtful of the propriety of imposing a tax upon the importation thereof at this time." The committee, however, recommended the imposition of an additional duty of one penny per pound on all nails or spikes imported into the state. The report of the committee was adopted.

Further evidence of the injurious effects of foreign competition upon our domestic iron industry immediately after the peace is furnished in the following extract from the account of Dr. John D. Schoepf's travels in the United States, published at Erlangen in 1788.

America is richly supplied with iron, especially in the mountainous districts, and the ore is moreover easily obtained; nevertheless, and in spite of the abundance of wood, at present European iron can be brought to America cheaper than the founders and forgers of that place are able to produce it, by reason of the high wages of the workmen. The owners of the iron works in the different provinces, particularly in Pennsylvania and Jersey, tried in vain to induce their governments to prohibit the importation of foreign iron, or to clog it with high duties. As this proposition conflicted directly with the interests of the members of the assembly, as well as with those of their fellow countrymen, it certainly could not be expected that they should decide to pay dearer for their native iron and iron implements, when foreigners could supply them cheaper. Formerly the Americans were able to send their pig and bar iron to England with advantage, for they were relieved of the heavy tax which Russian and Swedish iron paid there. This was the case principally from the middle colonies, and in the year 1768–'70 the exports to England amounted to about 2,592 tons of bar iron and 4,624 tons of pig iron, with which they paid for a part at least of their return cargoes in England. In return they took back axes, hoes, shovels, nails, and other manufactured iron implements, for, although some of these articles were occasionally manufactured in America just as good as in Europe, yet it could not be done under at least three times the cost. Therefore, up to this time, the manufacture of cast iron alone has been found to be particularly advantageous.

It was not until our second war with Great Britain that duties were so increased as to be really protective of domestic industries against foreign competition.

WAGES AND COST OF TRANSPORTATION IN THE IRON AND STEEL INDUSTRIES OF THE UNITED STATES AND GREAT BRITAIN.

The present condition of the iron and steel industries of the United States is one of great prosperity; yet they are subject to disadvantages from which the corresponding industries of other countries are relieved. It is true that it cannot now be said, as it was once said, that they lack the skill, or the capital, or the extensive and complete establishments of other countries; they are no longer infant industries in any sense; nor can it be said that the natural resources for the manufacture of iron and steel in our country are not abundant and varied. But in comparison with the iron and steel industries of other countries they are at a disadvantage in two important particulars. The wages of labor are much higher in this country than in any other ironmaking country in the world; and the raw materials of production, rich and abundant as they are, are in the main so remote from each other that a heavy cost for their transportation is incurred to which no other ironmaking country is subjected.

With reference to wages, a single illustration will show the disparity which exists in the iron and steel industries of this country and Europe. At Pittsburgh the price of puddling, or boiling, iron was fixed for one year on the 30th of May, 1881, in an agreement between the employers and their workmen, at a *minimum* of \$5.50 per ton, the price to be advanced if the price of bar iron should advance beyond 2½ cents a pound. Of the \$5.50 the puddler's helper receives about one-third. At Philadelphia, in an agreement between the employers and their workmen, on the 24th of July, 1880, the *minimum* price of puddling was fixed for an indefinite period, which still continues, at \$4 per ton, of which sum the helper receives about one-third. When the price of bar iron is

2½ cents a pound the price of puddling is to be $4.50 per ton, the helper to receive about one-third. If the price of bar iron advances beyond 2½ cents a pound the price of puddling is to be advanced. The Pittsburgh schedule of wages for puddling prevails in the western parts of the United States, and the Philadelphia schedule is fairly representative of the wages paid in eastern rolling mills. In England the wages of iron and steel workers are probably higher than in any other part of Europe. The north of England is the principal seat of the iron industry of that country. A board of arbitration and conciliation for the manufactured-iron trade of the north of England adjusts the wages of all rolling-mill workmen in the district every three months, upon the basis of the average net selling price of rolled iron during the three months preceding the month in which the board meets. The average net selling price of rolled iron for the three months which ended on the 30th of June, 1881, (a period of prosperity and good prices,) was £6 2*s.* 2*d.*, and the wages of puddlers for the three months beginning on the 1st of August was officially declared to be 7*s.* per ton, or about $1.75, of which sum the puddler's helper, in accordance with the English custom, receives about one-third. The official announcement of the adjustment of wages, dated July 29, is as follows: "In accordance with the sliding-scale arrangement and the resolution of the employers' meeting of February 24, the above-named figure of £6 2*s.* 2*d.* gives 7*s.* per ton as the rate for puddling over the three months commencing on the 1st of August, and a reduction of other forge and mill wages of 2½ per cent. upon last quarter." This announcement is signed by J. R. Winpenny and Edward Trow, secretaries. The difference in puddlers' wages in the north of England and at Pittsburgh and Philadelphia in the same period of time is thus seen to be very great. The wages of other rolling-mill workmen correspond with the wages of puddlers in both countries.

With regard to the cost of transporting raw materials in the United States and Europe, the testimony of a distinguished English ironmaster will be sufficient to show the great disparity which exists in the distances over which they must be transported. Mr. I. Lowthian Bell, a commissioner from Great Britain to the Philadelphia Exhibition of 1876, says in his official report: "The vast extent of the territory of the United States renders that possible which in Great Britain is physically impossible; thus it may and it does happen that in the former distances of nearly 1,000 miles may intervene between the ore and the coal, whereas with ourselves it is difficult to find a situation in which the two are separated by even 100 miles." From the ore mines of Lake Superior and Missouri to the coal of Pennsylvania is 1,000 miles. Connellsville coke is taken 600 miles to the blast furnaces of Chicago, and 750 miles to the blast furnaces of St. Louis. The average distance over which all the domestic iron ore which is consumed in the blast furnaces of the United States is transported is not less than 400 miles, and the average distance over which the fuel which is used to smelt it is transported is not less than 200 miles. Great Britain is our principal competitor in the production of iron and steel. In France, Germany, Belgium, Sweden, and other European ironmaking countries the raw materials of production may not be found in such close proximity as in Great Britain, but they lie much nearer to each other than is usual in the United States. Even when it is necessary to transport raw materials from one European country to another, as in taking the iron ores of Spain to England or Germany, the cost of removal is usually an unimportant consideration because of the short distances they are carried and the facilities which in most cases exist for carrying them by water. When this country is obliged, from any cause whatever, to import iron ores from Spain or from Mediterranean ports, the cost of transportation across the Atlantic and from the Atlantic ports inland imposes a heavy tax upon the consumer.

But it is not only on the raw materials that the cost of transportation operates as an impediment to low prices for manufactured products. The manufactured products themselves must frequently be transported long distances to find consumers. The conditions favorable to the production of iron and steel are not equal in many sections of the Union, and in some sections do not exist at all; iron and steel cannot, therefore, be extensively or profitably manufactured in all sections. The country, too, is of vast extent, while its railroad and other enterprises which consume iron and steel are found in every part of it. It is noticeable, also, that railroads form the principal means of communication between producers and consumers of iron in this country, and that railroad transportation is much more expensive than transportation by natural water routes. Heavy products of iron and steel, for instance, can be carried much more cheaply from Liverpool to the Gulf ports of the United States than from our own rolling mills and blast furnaces which are not situated on the sea-coast or on the Mississippi river, and very few of them are so situated. Iron and steel rails for railroads on the Pacific coast can be carried more cheaply from Liverpool to San Francisco than from Chicago or St. Louis.

To illustrate the influence of transportation charges upon the cost of production of iron and steel the following list of charges upon a few leading routes of transportation in the month of December, 1880, except on Lake Superior iron ores, which are for the summer of 1880, is appended.

1. Freight on the Pennsylvania railroad: The rate on iron ore, cinder, scrap iron, pig iron, blooms, and muck bars, from Philadelphia to Harrisburg, was $1.27 per 2,000 pounds, the distance being 110 miles; from Philadelphia to Johnstown, $2.60 per 2,000 pounds, the distance being 280 miles. These rates are by the car load, and average 1⅛ cents per mile per ton of 2,240 pounds.

The rate on coke from Everson to Harrisburg was $2.32 per 2,000 pounds, the distance being 235 miles; from Everson to Philadelphia it was $2.97 per 2,000 pounds, the distance being 345 miles. These rates are also by the car load, and average about 1 cent per mile per ton of 2,240 pounds.

The rate on manufactured iron from Pittsburgh to Philadelphia was $4 per 2,000 pounds, the distance being 360 miles; from Pittsburgh to New York it was $4.40 per 2,000 pounds, the distance being 452 miles. These rates average 1⅛ cents per mile per ton of 2,240 pounds.

2. Freight on Lake Superior ores: The average lake freight on iron ore from Marquette, Michigan, (the port of shipment near the mines,) to Lake Erie ports during the past season, including season charters and single trip charters, was from $2.50 to $2.65 per 2,240 pounds. The rail freight from Cleveland to Youngstown, 65½ miles, was $1 per 2,240 pounds; from Cleveland to Pittsburgh, which is 131 miles by one line and 151 miles by another, it was $2 per 2,240 pounds. These rail freights average about 1½ cents per mile per ton of 2,240 pounds.

3. Freight on Missouri ores: The railroad which furnishes the principal supply of ore for St. Louis furnaces charges 2½ cents per mile freight per ton, and other railroads in Missouri charge even a higher rate.

4. Freight on coke on Ohio railroads: From Connellsville, Pennsylvania, to Cleveland, Ohio, the freight on coke was $3 16 per 2,240 pounds, the distance being 188 miles by one line and 208 miles by another. The average of these rates is about 1⅔ cents per mile per ton of 2,240 pounds.

5. Freight on pig iron on western railroads, partly in Ohio: From the Mahoning valley, Ohio, to Chicago, Illinois, the rate was about $2.80 per 2,240 pounds, and the distance was about 385 miles, averaging about ¾ of a cent per mile per ton of 2,240 pounds.

SOME NOTABLE ACHIEVEMENTS BY AMERICAN IRON AND STEEL WORKS.

Without extended preface we now present a record of good work by American iron and steel works which has never been equaled in any other country. This record is compiled from information which we have obtained directly from the manufacturers, and relates to the operations of the past few years. It is not claimed that in every instance it gives the *best* work of the works mentioned, nor that it invariably gives the best work done at *any* iron and steel works in our country. While these pages are being prepared for the press better work than they record may have been achieved. Nor is it probable that every achievement that would have deserved a place in this chapter has been reported to us. Incomplete as it necessarily is, the record is valuable in affording a fair conception of our wonderful progress in the manufacture of iron and steel to the present time, and in furnishing the data for comparisons in after years.

BESSEMER STEEL WORKS.

The following statement embraces a correct and very full report of the operations of the Edgar Thomson Steel Works, with two converters, in the calendar year 1880, in tons of 2,240 pounds.

	Gross tons.	Pounds.
Ingots, 86.50 per cent	123,303	1,710
Scrap from converters, 3.12 per cent	4,445	1,805
Loss in conversion, 10.38 per cent	14,799	2,122
Ingots bloomed	123,676	810
Blooms produced, 94.19 per cent	116,487	450
Scrap produced in blooming department, 4.01 per cent	4,965	2,050
Loss in blooming, 1.80 per cent	2,222	2,190
Blooms rolled	111,705	1,710
Rails produced, 89.60 per cent	100,094	1,064
Scrap produced in rail department, 7.14 per cent	7,971	156
Loss in rail mill, 3.35 per cent	3,640	488
Average number of tons steel per cupola		655.86
Average number of tons steel per vessel lining		12,330.00
Average number of tons steel per vessel bottom		90.00
Average number of tons steel per steel ladle		91.62
Average number of tons steel per ingot mold		110.00

In the twelve months ending January 31, 1881, the two converters of the Edgar Thomson Steel Works made 130,694 gross tons of Bessemer steel ingots; the steel-rail mill rolled 106,722 tons of steel rails; and the billet mill rolled 3,421 tons of billets.

The production of the Edgar Thomson Steel Works in the six months ending June 30, 1881, was as follows: Ingots, 76,758 gross tons; rails, 65,087 tons; forgings, 1,193 tons. The largest runs made in these six months were as follows: Best 24 hours, 623 tons of ingots and 534 tons of rails; best week, 3,433 tons of ingots and 2,823 tons of rails; best month, 14,033 tons of ingots and 11,673 tons of rails. But two converters were used. The percentage of increase in the production of ingots in the first six months of 1881 over the same period in 1880 was 38.48, and in the production of rails it was 50.40.

The Edgar Thomson Steel Works, with two converters, made the following product in the ten months ending October 31, 1881: Ingots, 129,284 gross tons; rails, 112,835 tons; forgings, 1,226 tons. The largest runs made in these ten months were as follows: Best 24 hours, 654 tons of ingots and 578 tons of rails; best month, 14,461 tons of ingots and 13,246 tons of rails. In the week ending November 5, 1881, these works surpassed their previous record, making 3,580 tons of ingots and 3,112 tons of 56-pound rails, but they subsequently exceeded even this large product. In November, 1881, a thirty-day month, they produced 16,193 tons of Bessemer steel ingots and 13,646 tons of rails. The best week's work was 3,902 tons of ingots and 3,202 tons of 56-pound rails. The best 24-hours' work was 700 tons of ingots and 608 tons of 56-pound rails.

In the twelve months ending January 31, 1881, the two converters of the Cambria Iron Company made 126,194 gross tons of Bessemer steel ingots. In the month of January they made 13,343 tons of ingots. In the week ending January 29 they made 3,318 tons of ingots. The best 24 hours' work was 595 tons of ingots.

The blooming mill of the Cambria Iron Company rolled 127,837 gross tons of blooms in 1880; its best month's work was 14,709 tons in March, 1881; its best week's work was 3,306 tons in the week ending November 27, 1880; its best day's work was 612 tons on February 28, 1881.

The rail mill of the Cambria Iron Company rolled 9,985 gross tons of steel rails in May, 1881; in the week ending May 21, 1881, it rolled 2,415 tons.

The Bethlehem Iron Company, with two converters, in October, 1881, made 14,646 gross tons of ingots. Its best week's work was 3,857 tons, and best 24 hours' work was 654 tons. Although the Bethlehem Iron Company has four converters it had at the time sufficient blowing apparatus for only two of them. One of the two new converters was, however, occasionally used in place of one of the two old ones.

The best work by the Bethlehem Iron Company's blooming mill and steel-rail mills has been as follows: Best 24 hours, 679 gross tons of blooms and 458 tons of rails; best week, 3,589 tons of blooms and 2,875 tons of rails; best month, 14,663 tons of blooms and 11,336 tons of rails. In the same month for which the rail production is here given the billet mill rolled 1,214 tons of steel billets.

In the week ending September 11, 1880, the Lackawanna Iron and Coal Company's steel works made 2,830 gross tons of Bessemer steel ingots with two converters. The steel-rail mill in the same week made 2,156 tons of first-quality Bessemer steel rails.

In the week ending October 29, 1881, the two converters of the Albany and Rensselaer Iron and Steel Company made 2,906 gross tons of Bessemer steel ingots; the blooming mill rolled all of these ingots. In this week the best 8 hours' work was 210 tons of ingots; the best 24 hours' work was 544 tons of ingots. The rail mill rolled 2,230 tons of steel rails in this week.

In the month of October, 1881, the Albany and Rensselaer Iron and Steel Company, with two converters, and but three cupolas—running only two of them at one time, made 11,629 gross tons of Bessemer steel ingots; the blooming mill rolled all of these ingots, and the rail mill rolled 8,748 tons of steel rails; the 18-inch steel merchant train rolled 1,070 tons of steel billets and merchant bars; the 16-inch train rolled 1,398 tons of steel billets and merchant bars, losing one week owing to repairs; the sheet mill rolled 343 tons of steel slabs and sheets; the 9-inch train rolled 332 tons of merchant steel.

In the month of January, 1880, the two converters of the Joliet Steel Company produced 10,640 gross tons of Bessemer steel ingots, and the steel-rail mill, although four turns were lost, produced in the same time 8,000 tons of Bessemer steel rails.

The steel works of the Vulcan Steel Company, at Saint Louis, were not put in complete running order until September, 1881. Their record for October is as follows: Ingots, 8,977 gross tons; blooms, 7,778 tons; rails, 6,403 tons.

ANTHRACITE BLAST FURNACES.

One of the furnaces of the Bethlehem Iron Company, at Bethlehem, Pennsylvania, 70 feet by 17 feet, made 1,737 gross tons of pig iron in one month, 428 tons in one week, and 61 tons in one day in 1878.

The Crane Iron Company's furnace No. 5, at Catasauqua, Pennsylvania, 65 feet by 18 feet, made 340 gross tons of No. 1 foundry pig iron in one week in August, 1875; in four weeks it made 1,301 tons.

One of the Coleraine furnaces, at Redington, Northampton county, Pennsylvania, 60 feet by 18 feet, made 13,193 gross tons of pig iron in 1874; weekly average, 253½ tons.

The Durham furnace, belonging to Cooper & Hewitt, situated at Riegelsville, Bucks county, Pennsylvania, 76 feet by 20 feet, made 425 gross tons of pig iron in the week ending May 31, 1879; the largest day's work was 65 tons. On Saturday, June 7, the product was 70 tons.

The No. 1 furnace of the Lackawanna Iron and Coal Company, at Scranton, Pennsylvania, during the fourteen weeks ending March 13, 1880, made an average of 544 gross tons weekly, and the Franklin furnace, owned by the same company, but situated in Sussex county, New Jersey, made, during the same time, 478½ tons weekly. Each furnace is 67 feet by 21½ feet.

The furnace of the Warwick Iron Company, at Pottstown, Pennsylvania, 55 feet by 16 feet, made the following record in the two weeks ending May 24 and 31, 1879, respectively.

Cubic feet of air used per minute	8,655	8,655
Pressure of blast	8.40	8.60
Area of all tuyere nozzles	57.60	57.60
Tons of pig iron produced (2,268 pounds)	414	410
Tons of coal consumed per ton of iron	1.24	1.25
Cubic feet of air to one ton of iron	201,696	196,296
Cubic feet of air consumed per pound of coal	72.61	70.55
Minutes stopped during week	433	782
Yield of ore, per cent	48.78	46.51
Temperature of blast, Fahrenheit	825°	825°

The furnace of the Pottstown Iron Company, at Pottstown, Pennsylvania, in the week ending February 26, 1881, made 461 gross tons of pig iron. The dimensions of the furnace are 60 feet by 16 feet.

The No. 1 furnace of the Phœnix Iron Company, at Phœnixville, Pennsylvania, made the following record for the week ending April 23, 1881.

Dimensions	15 feet bosh, 52 feet working height.
Pig iron made	456.13 gross tons.
Fuel used per ton of pig iron	2,464 pounds.
Temperature of blast, Fahrenheit	840°.
Blast pressure	8 pounds.
Revolutions of engine, 7 feet by 7 feet	20
Volume of air per minute	10,775 cubic feet.
Yield of ore	50 per cent.
Burden	1.6 tons ore to 1 ton of coal.
Quality of iron	Open gray.
Extraordinary stoppage	6 hours.

The No. 3 furnace of the Phœnix Iron Company, 58 feet by 14 feet, in the week ending July 23, 1881, made 359.6 gross tons of pig iron, consuming 2,954 pounds of anthracite coal per ton of pig iron made; in the week ending September 17, 1881, it made 397.5 tons.

One of the Onondaga furnaces, at Geddes, New York, 60 feet by 15 feet, *on part coke*, made 2,093 gross tons of pig iron in two months in 1876.

The Clove furnace of the Parrott Iron Company, in Orange county, New York, 55 feet by 16 feet, made a continuous blast of 10 years and 19 days, from May 26, 1871, to June 14, 1881, during which time it produced 101,245 tons of pig iron of 2,240 pounds to the ton, 75 per cent. of which was No. 1 foundry pig iron. The fuel used for the first seven years was exclusively anthracite coal, but in the last three years a small quantity of coke was occasionally used as a mixture.

BITUMINOUS BLAST FURNACES.

On March 28, 1880, the A furnace of the Edgar Thomson Steel Works, near Pittsburgh, Pennsylvania, 65 feet by 13 feet, made 113 gross tons of pig iron, with a consumption of 1,965 pounds of coke per ton of pig iron, and on ores yielding 54.02 per cent. The B furnace, 80 feet by 20 feet, made 208 tons of pig iron on November 22, 1880. The C furnace, 80 feet by 20 feet, made 224 tons of pig iron on April 28, 1881, the fuel consumption being at the rate of a ton of coke to the ton of pig iron. The best week's work of the C furnace was 1,357 tons, and the best month's work was 5,598 tons.

In the week ending March 28, 1879, the Lucy furnace No. 1, 75 feet by 20 feet, at Pittsburgh, Pennsylvania, made 857 gross tons of pig iron; in the seven days ending March 31 it made 945 tons; in the month of March it made 3,684 tons, a daily average of 118 tons. On November 21, 1880, it made 202 tons in 24 hours.

The Isabella furnace No. 1, at Etna, Allegheny county, Pennsylvania, 75 feet by 18 feet, made 702 gross tons of pig iron in one week in 1875. The Isabella furnace No. 2, 75 feet by 20 feet, made 770 tons in one week in November, 1875; its best day's work in the same week was 116 tons. In one calendar month in 1875 it made 3,163 tons. No. 1 has recently been widened to 20 feet, and has made 1,130 tons in one week in 1881.

One of Shoenberger, Blair & Co.'s furnaces, at Pittsburgh, Pennsylvania, 65 feet by 13½ feet, made 423 gross tons of pig iron in one week in December, 1876.

One of Laughlin & Co.'s Eliza furnaces, at Pittsburgh, Pennsylvania, 61 feet by 16 feet, made in one day, in 1880, 130 gross tons of pig iron; in two consecutive days it made 253 tons.

The Neshannock furnace, at New Castle, Pennsylvania, 60 feet by 16 feet, made 679 gross tons of pig iron in one week in December, 1881, its daily product being 82, 83, 91, 97, 104, 108, and 114 tons.

The Ormsby furnace, at Sharpsville, Mercer county, Pennsylvania, 50 feet by 12 feet, made 301 gross tons of pig iron in the week ending January 22, 1876.

The Rebecca furnace of the Kittanning Iron Company Limited, at Kittanning, Armstrong county, Pennsylvania, 65 feet by 16 feet, made 475 gross tons of pig iron in one week in March, 1881.

Dunbar furnace No. 1, at Dunbar, Fayette county, Pennsylvania, 77 feet by 20 feet, made in a thirty-day month, in 1880, 2,182 gross tons of pig iron on 83 bushels of coke to the ton; the ores yielded for that month 42.5 per cent. of metallic iron. The best week's work during the month was 520 tons, and the best day's work was 80 tons. The best three days' work during this entire blast was 83, 85, and 87 tons, respectively.

The Centennial furnace of the Cambria Iron Company, at Johnstown, Pennsylvania, 75 feet by 20 feet, made 578 gross tons of pig iron in one week in May, 1877.

The No. 2 furnace of the Pennsylvania Steel Company, at Steelton, Dauphin county, Pennsylvania, 75 feet by 20 feet, on fuel consisting of one-third anthracite and two-thirds coke, made 2,916 gross tons of pig iron in November, 1878; 725 tons in one week; and 107 tons in one day.

The furnace of the Low Moor Iron Company of Virginia, at Low Moor, Alleghany county, Virginia, 75 feet by 18 feet, made 110 tons of pig iron on October 8, 1881, each ton weighing 2,300 pounds; 703 tons in the week ending October 8, 1881; and 2,563 tons in the month of September, 1881. The fuel used was coke made at the company's coke ovens from New river coal.

The Longdale furnace No. 1, at Longdale, Alleghany county, Virginia, 60 feet by 11 feet, made 35 gross tons of pig iron on April 11, 1879; 219½ tons in the week ending February 29, 1879; and 874 tons in the month ending April 19, 1879.

The furnace of James C. Warner & Co., at Rising Fawn, Dade county, Georgia, 63 feet by 16 feet, made 91 tons of pig iron in one day in June, 1881, each ton weighing 2,268 pounds; 575 tons in one week in the same month; and 2,271 tons in the whole of the same month. The fuel used was coke.

The Riverside furnace, at Wheeling, West Virginia, 75 feet by 16½ feet, made 829 gross tons of pig iron in the week ending November 6, 1881. The daily record was as follows, omitting fractions: 113, 115, 113, 121, 121, 121, and 122 tons.

The Struthers furnace, at Struthers Station, Mahoning county, Ohio, 54 feet by 16 feet, made 2,061 gross tons of pig iron in the month ending November 28, 1877; its best week's work was 507¼ tons; its best 7 days' work was 538 tons.

On January 19, 1881, the No. 2 furnace of the Southern States Coal, Iron, and Land Company, at South Pittsburg, Marion county, Tennessee, 70 feet by 20 feet, made 92 tons of pig iron, each ton weighing 2,268 pounds; in the week ending April 9, 1881, it made 511 tons; in the month of August, 1881, it made 2,146 tons. The fuel used was coke.

The No. 1 furnace of the Joliet Steel Company, at Joliet, Illinois, 72 feet by 20 feet, made 126 gross tons of pig iron in one day in 1881; 788 tons in the week ending April 8, 1881; and 3,276 tons in the month of April, 1881.

One of the Milwaukee Iron Company's furnaces, at Milwaukee, Wisconsin, 66 feet by 17 feet, made 375 gross tons of pig iron in one week in July, 1875.

CHARCOAL BLAST FURNACES.

The Katahdin furnace, in Piscataquis county, Maine, 50 feet by 10 feet, made in one week, in 1881, 121 gross tons of car-wheel pig iron, on a consumption of 83 bushels of charcoal to the ton, from ore averaging 54 per cent.

The Lanesborough furnace, at Lanesborough, Massachusetts, 33 feet by 9½ feet, made 5,841 gross tons of car-wheel pig iron in 89 successive weeks, ending April 21, 1874.

Furnace No. 1 of the Barnum Richardson Company, at East Canaan, Connecticut, 32 feet by 9 feet, made 121 gross tons of car-wheel pig iron in the week ending October 1, 1881, which is the best week's work ever done by a furnace in that state.

The Muirkirk furnace, at Muirkirk, Maryland, 27 feet by 8½ feet, made 72 gross tons of car-wheel pig iron in one week, in 1878, from lean Maryland ores, of which it took 2¾ tons to make one ton of pig iron.

The furnace of the Bangor Iron Company, at Bangor, Van Buren county, Michigan, 43 feet by 9⅝ feet, made the following record in twelve months ending June 30, 1880.

Tons of iron ore smelted	24,596.3
Bushels of charcoal consumed (2,748 cubic inches)	1,458,350
Tons of limestone flux used	841
Gross tons of pig iron made	14,653½
Charges run	58,334
Bushels of coal used per ton of iron made	99.52
Average yield of ore, per cent	59.57
Pounds of flux per ton of iron	134
Average burden carried, pounds	946
Cubic feet of air used per ton of iron	104,242
Pounds of air per pound of iron	3.53
Number of days run	352.3
Average daily product, gross tons	41.54

The best week's work of this furnace in 1880 was 356 gross tons.

The following work was done in 1879 by the Elk Rapids furnace in Antrim county, Michigan, 47 feet by 12 feet, in tons of 2,260 pounds.

	Tons.	Pounds.
Pig iron made week ending August 30	316	1,308
Pig iron made week ending September 6	313	655
Pig iron made week ending September 13	335	1,145
Pig iron made week ending September 20	335	2,080
Total	1,301	668

The average make per day for these four weeks was 46 tons; largest day's make, 51 tons; smallest day's make, 42 tons. The furnace had then been in blast 478 days, and had made an average of 39 tons daily.

The Menominee furnace, at Menominee, Michigan, 44 feet by 9½ feet, made 301 gross tons of pig iron in the week ending April 21, 1877; the largest 24 hours' make was 46 tons.

The Bay furnace No. 1, at Onota, Schoolcraft county, Michigan, 40 feet by 9 feet, made 264 gross tons of pig iron in the week ending August 22, 1875.

The Bay furnace No. 2, at Onota, Michigan, 45 feet by 9½ feet, made 1,109 gross tons of pig iron in August, 1875; the best week's work was 276½ tons; the best day's work was 41½ tons.

The Munising furnace, at Munising, Schoolcraft county, Michigan, 40 feet by 9 feet, made 184 gross tons of pig iron in the week ending February 22, 1874.

The furnace of the Spring Lake Iron Company, at Fruitport, Muskegon county, Michigan, 46 feet by 11 feet, made 343 gross tons of pig iron in the week ending March 27, 1880—an average of 49 tons a day.

The Scotia furnace, at Leesburg, Crawford county, Missouri, 40 feet by 9⅓ feet, made 16,544 gross tons of pig iron in 19½ months, ending December 16, 1875.

The furnace of the Nova Scotia Iron Company, in Dent county, Missouri, 55 feet by 11 feet, made 62 gross tons of pig iron on September 13, 1881; 389 tons in the week ending September 25, 1881; and 1,405 tons in the month of September, 1881. This is a new furnace, blown in for the first time on July 31, 1881.

In September, 1881, the Midland furnace, in Crawford county, Missouri, 50 feet by 10 feet, made 1,372 gross tons of pig iron, using 85.81 bushels of charcoal per ton of iron made. Counting 25 pounds to the bushel of charcoal, the consumption of fuel per ton of pig iron was 2,145.25 pounds; at 22 pounds to the bushel, the usual allowance, the consumption per ton would be but 1,887 pounds.

On June 19, 1881, the Tecumseh furnace, in Cherokee county, Alabama, entered on the seventh year of its blast on one hearth without blowing out. The dimensions of the furnace are 60 feet by 12 feet, and it makes 20 gross tons of pig iron per day. This furnace made 656 gross tons of pig iron in October, 1878.

CONSUMPTION OF FUEL TO THE TON OF PIG IRON.

The following information was collected for this chapter by Messrs. Taws & Hartman, of Philadelphia, and shows the consumption of fuel in making one ton of pig iron, together with other necessary details, at eleven prominent coke and anthracite furnaces in the United States, taken from an average of six consecutive weeks' work in each case in the summer of 1881.

Details.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.
Bosh ....feet.	18	11	13	20	18	16	15	17	20	20	17
Height ....do..	78	60	65	75	70	70	56	70	80	75	65
Fuel to ton of pig iron ....pounds.	2, 227	2, 264	2, 314	2, 900	2, 987	2, 822	2, 603	2, 357	2, 400	2, 677	2, 618
Carbon in fuel ....per cent	85	94	85	82	88	85	87.4	83	85	87	86
Ore to ton of pig iron ....pounds.	2, 610	4, 816	4, 099	2, 481	4, 480	4, 239	3, 413	3, 920	3, 071	4, 212	4, 362
Rolling-mill cinder to ton of pig iron.....do..	1, 030	....	....	1, 230	....	....	488	....	....	....	....
Limestone to ton of pig iron........do..	1, 546	1, 355	1, 815	1, 756	2, 240	1, 815	1, 050	983	1, 339	2, 309	1, 107
Quality of pig iron ....numbers	1, 2, 3	3, 4	1	1, 2, 3	1, 2	2	2, 3, 4	3	1	2, 3	1, 2 Bessemer.
Heat of blast	1, 150°	750°	1, 050°	1, 150°	1, 100°	1, 348°	870°	1, 371°	1, 080°	765°	750°
Kind of fuel used........	Coke.	Coke.	Coke.	Coke.	Anthracite	Anthracite	Anthracite	⅓ coke ...... ⅔ anthracite.	Coke.	⅛ coke ..... ⅞ anthracite.	⅛ coke. ⅞ anthracite.
Average weekly production of pig iron, in tons of 2,268 pounds........	700	170	562	986	470	292	403	359	1, 274½	527	390

The following information was collected for this chapter by Mr. John Birkinbine, of Philadelphia, and shows the working of eleven charcoal furnaces in the United States in 1881, taken from an average of six consecutive weeks' work. The consumption of fuel per ton of pig iron will be compared by the reader with the corresponding figures given in the table above.

Details.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.
Bosh........feet.	8	10½	9⅝	10	10	9⅓	10⅓	11	10	8⅓	9½
Height........do..	47	50	45	53	43	40	52	45	59	29	36
Fuel to ton of pig iron ....pounds.	1, 691	1, 750	1, 848	1, 890	1, 930	1, 960	1, 970	1, 980	2, 121	2, 410	2, 631
Carbon in fuel (estimated)........per cent.	94	95	95	94	93	94	95	94	94	90	90
Ore to ton of pig iron........pounds.	3, 756	3, 670	3, 997	3, 961	3, 720	4, 300	3, 770	3, 690	4, 806	4, 827	6, 105
Limestone to ton of pig iron........do..	164	183	153	50	130	600	151	136	472	690	1, 680
Quality of pig iron ....numbers.	1, 2, 3	Carwheel	Bessemer, Carwheel	Bessemer	Carwheel	Bessemer	Carwheel, Malleable	Bessemer, Carwheel	Carwheel	Carwheel	Forge.
Heat of blast	750°	750°	425°	925°	850°	650°	860°	850°	700°	850°	850°
Average weekly production of pig iron, in tons of 2,268 pounds........	178. 3	204	183	316. 5	312. 8	238. 8	266	344. 2	113. 1	80. 2	108. 5

In these two tables American blast-furnace practice may be said to be epitomized, and they sufficiently establish the fact that in this practice all of the economies known in the production of pig iron are employed.

The following details show small fuel consumption in smelting lean ores by the furnace of the Furnaceville Iron Company, in Wayne county, New York, in 1881.

Dimensions of furnace	50 feet by 11 feet.
Average yield of ore for five weeks	40.58 per cent.
Temperature of blast	845 degrees.
Burden per gross ton of coal	1.762 tons of ore.
Anthracite coal used per ton of pig iron made	3,132 pounds.

With an ore yielding 56½ per cent. the consumption of coal would have been but 2,251 pounds.

IRON ROLLING MILLS.

The Union Iron Company of Buffalo, New York, in July, 1874, rolled two beams 15 inches deep, having two flanges 5⅝ inches wide and web five-eighths of an inch thick. The beams, including crop ends, were 53 feet long; the piles weighed 3,851 pounds, and were 13 feet 5 inches long; the finished beams weighed 200 pounds to the yard, were 50 feet in length, and the total weight of each was 3,333 pounds.

The Phœnix Iron Company, of Phœnixville, Pennsylvania, in October, 1881, rolled a 1½-inch "guide round" bar of iron, which, when trimmed, measured 65 feet 5 inches in length, and a ¾-inch "guide round" bar which trimmed 116 feet.

In seven weeks ending May 3, 1879, the Central Iron Works, at Harrisburg, Pennsylvania, made 1,070 gross tons of boiler plate and tank iron from three heating furnaces. The last week's work was 177½ tons, and the average of the last three weeks was 171 tons.

The Pennsylvania Iron Works, at Danville, Pennsylvania, in 12 hours, in October, 1874, heated, rolled, straightened, and punched, ready for use, 156 gross tons of iron rails, using one train of rolls.

Graff, Bennett & Co., of Pittsburgh, Pennsylvania, in October, 1875, rolled some thin sheet iron, of which it took 15,500 leaves to make an inch in thickness.

The Iron and Steel Company of Ironton, Ohio, in September, 1874, rolled a thin sheet of iron, a piece of which, 3 inches wide by 5 inches long, weighed only 19 grains.

The Cleveland Rolling Mill Company, of Cleveland, Ohio, on October 12, 1877, rolled 51,030 pounds of No. 4 wire rods in 9 hours.

NAIL FACTORIES.

The Wheeling Iron and Nail Company, of Wheeling, West Virginia, in February, 1874, cut 6,826 kegs of nails in one week with 105 machines. One man cut 176 kegs of eightpenny nails that week.

In the week ending May 3, 1879, Charles L. Bailey & Co.'s Chesapeake nail works, at Harrisburg, Pennsylvania, made 3,782 kegs of cut nails with 66 nail machines, running single turn.

CRUCIBLE STEEL WORKS.

Park, Brother & Co., of Pittsburgh, Pennsylvania, in September, 1874, rolled a crucible steel plate 180 inches long, 53 inches wide, and three-fourths of an inch thick, weighing 2,700 pounds.

Singer, Nimick & Co., of Pittsburgh, Pennsylvania, in July, 1877, rolled for Emerson, Smith & Co., of Beaver Falls, Pennsylvania, a band saw in one continuous piece, 54 feet long, 8 inches wide, and of No. 15 gauge.

FORGINGS.

In May, 1881, the Nashua Iron and Steel Company, of Nashua, New Hampshire, forged a steamboat shaft weighing 20,230 pounds from an open-hearth steel ingot weighing 26,000 pounds. The largest hammer owned by this company is rated at ten tons, and is double-acting, the steam following the piston in its descent. Iron shafts weighing 15 tons can be readily worked under this hammer.

The Reading Iron Works, at Reading, Pennsylvania, have five hammers in their forge department, weighing from 750 pounds to 10 tons. One marine shaft made by them during the civil war weighed 42 tons.

THE LARGEST STEAM HAMMER.

On the 6th of September, 1881, Park, Brother & Co., of Pittsburgh, put in operation for the first time their 17-ton steam hammer, which is the largest in the United States. It will work steel ingots 2 feet square. The hammer itself was built by Wm. B. Bement & Son, of Philadelphia. The anvil, which is the heaviest iron casting ever made in this country, weighing 160 tons, was cast a few feet from its place with five cupolas, under the direction of Park, Brother & Co., on October 5, 1880; its dimensions are 11 feet high, 8 by 10 feet at the base, and tapering to 4 by 6 feet at the top. The hammer and its fittings occupy a ground space 26 feet long by 13 feet wide. Its height from the ground is 32 feet. The framing is of wrought-iron plates from ⅞ of an inch to 1⅛ inches thick, bolted and riveted and strengthened with angle irons. The weight of the cast-iron cylinder is about 11 tons, the bore 40 inches, and the stroke 9 feet. The piston, rod, ram, and die weigh about 17 tons. When the steam is admitted on top of the piston it will produce an additional force or weight of about 50 tons, making 67 tons pressure in all when the ram or hammer is stationary. The whole cost of the hammer, anvil, and fittings, ready for operation, is estimated at $52,000.

HEAVY CASTINGS.

In the spring of 1881 a large steam cylinder was cast in the city of New York at the Morgan iron works of John Roach & Co. It was intended for a vessel for the Old Colony Steamboat Company. The weight of the rough casting was 30 tons. This cylinder has a stroke of 16 feet 1½ inches, and a diameter of 110 inches.

On the 24th of October, 1881, the breech section of a large cannon was cast in the city of Reading, Pennsylvania, by the Reading Iron Works. The weight of the rough casting was 20 tons. The breech section is 15 feet in length. The barrel section will be 10 feet long, to be made of steel by the Midvale Steel Company, and the entire length of the cannon will be 25 feet. It is a Lyman-Haskell accelerating gun, intended to throw a ball 12 miles, although it will have but a 6-inch bore.

In July, 1862, the I. P. Morris Company's Port Richmond iron works, at Philadelphia, cast an anvil block for a steam hammer for the Lackawanna Iron and Coal Company which was 9 feet square at the base and 7 feet 9 inches high, its rough weight being 61,000 pounds.

During the civil war Charles Knap's Fort Pitt foundry, at Pittsburgh, then under the management of William Metcalf, cast several 20-inch Rodman guns weighing 80 tons in the rough and 116,000 pounds when finished. For each of these guns 100 tons of iron was melted to provide against accidents.

In 1881 the Atlas Works, at Pittsburgh, cast two anvils for the Siemens-Anderson Steel Company, which weighed 22 tons and 16 tons, respectively.

IRON AND STEEL RAILS.

The excellent wearing qualities of American iron rails have been conclusively demonstrated by long experience. This was illustrated at the Philadelphia Exhibition in 1876, when the Cambria Iron Company displayed an iron rail that had been in use nineteen years, three rails that had been in use eleven years, and five rails that had been in use ten years, all under severe wear. The same company also exhibited two iron rails which bridged a gap 12 feet wide and 12 feet deep that had been washed out under the track of a western railroad, and which carried safely over the gap an engine weighing 57,400 pounds and a train of seven cars. The American Iron and Steel Association collected a mass of statistics in 1879 from American railroads relative to the wear of domestic and foreign steel rails, and the general conclusion was derived that American steel rails are superior to English steel rails, while the testimony of the Pennsylvania Railroad Company demonstrated that the American steel rails which had been laid in its tracks were wearing almost twice as well as the foreign steel rails it was also using.

AN INNOVATION IN THE EMPLOYMENT OF LABOR.

In this connection reference may be made to the innovation which has taken place at a few of the blast furnaces and steel works of the country in dividing the day of 24 hours into three turns, or shifts, of 8 hours each, with one set of hands for each turn. The recent experience of the general superintendent of the Edgar Thomson Steel Works may be quoted in favor of the proposition that this new departure in the employment of labor in exhausting situations at American iron and steel works is beneficial alike to the employer and his workmen. He says: "In increasing the output of these works I soon discovered that it was entirely out of the question to expect human flesh and blood to labor incessantly for 12 hours; therefore it was decided to put on three turns, reducing the hours of labor to 8. This has proved to be of immense advantage to both the company and the workmen, the latter now earning more in 8 hours than they formerly could in 12 hours; while the men can work harder constantly for 8 hours because they have 16 hours for rest."

FOREIGN TESTIMONY TO THE EXCELLENCE OF AMERICAN METALLURGICAL PRACTICE.

English technical journals frankly confess the superior skill and mechanical enterprise displayed in the management of the iron and steel works of the United States. On the 7th of January, 1881, *The Engineer*, of London, said:

> The United States ironmasters are beating us by 100 per cent. in the output from their plant. With one pair of converters they can do as much as and more than we can do with two pairs; and, while our blast furnaces turn out 480 tons of pig per week, theirs, much smaller, give as much as 1,100 tons a week. In the rail mills, and bar and sheet mills, matters are in much the same condition. If we are asked to what is this superiority due, we reply that it is to be traced, to some extent, to better organization, and in others to better plant. In the Bessemer works, for example, the drill of the men employed is perfect, and a converter is never stopped for days while being lined up and rebottomed. The converter alone represents but a small part of the plant; but when a converter is standing so to a certain extent do the blowing engines, the hydraulic appliances, ingot molds, and very probably the hammer, the cogging mill, and the rail train. What would be thought of a foundry which was closed while a 5-ton ladle was being relined? In the United States, for a long time back, the moment a converter is burned out it is taken away, and a new one put in its place. The operation requires, we understand, about half an hour at the most. In how many English steel works is the same plan pursued? A great deal of the blast-furnace plant of Great Britain is antiquated, and the sooner it is replaced with more modern plant the better. We may cite, as an

example, hot-blast stoves. It is a suggestive fact that much of the success which attends the labor of the American ironmasters is due to the efficiency of Mr. Cowper's stoves, and yet English ironmasters have been very slow to accept an invention which American ironmasters jumped at.

On the 26th of August, 1881, *Iron*, of London, thus acknowledged the superiority of American tools, made, of course, of American iron and steel.

There are many articles in the production of which greater taste might be cultivated to much advantage, a matter in which, as a nation, we have never excelled, and in respect of which several foreign countries are a long way ahead of us. An example which will readily present itself to many minds is to be found in the superiority of the tools which are now so largely imported into this country from America, and which, while remarkable for their quality and finish, are much less costly than those of English production.

SOME OF THE IMPORTANT USES OF IRON AND STEEL IN THE UNITED STATES.

The people of the United States are the largest *per capita* consumers of iron and steel in the world, and of all nations they are also the largest aggregate consumers of these products. Great Britain makes more iron than we do, but she exports about one-half of all that she makes. She exports more than one-half of the steel that she makes, and yet makes but little more than this country. No other European country equals Great Britain either in the *per capita* or aggregate consumption of iron and steel. This country is not now producing as much iron and steel as it consumes, but imports large quantities of both products, Great Britain being the principal source of our foreign supply. Our exports of iron and steel are only nominal.

A simple enumeration of some of the more important uses to which iron and steel are applied by our people will show how prominent is the part these metals play in the development of American civilization and in the advancement of our greatness and power as a nation.

We have built almost as many miles of railroad as the whole of Europe, and consequently have used in their construction almost as many rails, and now use almost as many railroad cars and locomotives. At the close of 1881 this country had 100,000 miles of railroad, Europe had about 106,000 miles, and all the rest of the world had about 45,000 miles. The United States had 19 miles of railroad to every 10,000 of population, while Europe had a little more than 3 miles to the same population. Railroads, it is well known, annually consume more than one-half of the world's production of iron and steel—rails, bridges, cars, and locomotives being impossible without these metals. The street railway is an American invention which also consumes large quantities of iron and steel, and we are far in advance of every other nation in its use. We were also the first nation in the world to introduce elevated railways especially to facilitate travel in large cities. In the construction of our New York elevated railways beauty of design, fitness of parts, and strength of materials have been so perfectly combined as to excite the admiration of all who behold them. We are the foremost of all nations in the use of iron and steel in bridge-building for railroads and ordinary highways, and the lightness and gracefulness of our bridges are nowhere equaled, while their strength and adaptability to the uses for which they are required are nowhere surpassed. In the use of iron for water pipes and gas pipes we are probably in advance of every other nation. We make more iron stoves for heating halls and dwellings and for the purposes of the kitchen than all the rest of the world, and in the use of heaters and ranges we are behind no other nation. Our household stoves, both for heating and cooking, are works of real art as well as of utility. They are ornaments of American homes, instead of being conveniences simply. Our heating stoves are especially handsome, bright, cheerful, healthful, and clean. In all respects they form the best combination of desirable qualities yet devised for the heating of private dwellings. Cooking and other domestic utensils of iron have always, even in colonial days, been freely used in American households. We make liberal use of both cast and wrought iron in the construction of public and private buildings. Our use of iron for these purposes has in late years been quite marked, and in no respect more so than in the truly artistic effects which we give to this metal. We probably excel all nations in the use of iron for ornamental purposes in connection with masonry, brick-work, and wood-work. Fine illustrations of the artistic combination of iron with other materials may be seen in the interior of the new State Department building at Washington and in the interior of the new passenger depot of the Pennsylvania railroad at Philadelphia. We lead the world in the use of iron and steel wire for fencing purposes, and we have more miles of telegraph wire in use than any other country. Barbed wire fencing is an American invention. We have made creditable progress in the construction of iron ships, and we would have made much greater progress if the same encouragement that has been given by other nations to their shipping interests had been given to ours. We use immense quantities of plate iron in the storage, transportation, and refining of petroleum, in the production of which nature has given us almost a monopoly. The oil wells themselves yearly require thousands of tons of iron pipes for tubing. We make liberal use of plate and sheet iron in the construction of the chimneys of steamboats on our lakes and rivers, and in the construction of factory, rolling-mill, and blast-furnace chimneys, and the stacks of blast furnaces. American planished sheet iron has almost entirely superseded Russia sheet iron in our markets. We use it for locomotive jackets, in the manufacture of stoves and stove-pipe, and for many other purposes. We are the largest consumers of tin plates in the world—Great Britain, their principal manufacturer, sending us annually more than one-half of her whole product. Portable and stationary engines consume large quantities of iron and steel. Our beautiful steam fire-engines are the product of American taste and skill, if they are not strictly an

American invention, and we annually make large numbers of them for home use and for exportation. Anchors and chains, cotton-presses and cotton-ties, sugar-pans and salt-pans, and general foundry and machine work annually require large quantities of either iron or steel. We make our own cotton and woolen manufacturing machinery, and nearly all the other machinery that we use. The manufacture of the printing presses of the country consumes immense quantities of iron and steel. No other country makes such free use of the printing press as this country. We are the leading agricultural nation of the world, and hence are the largest consumers of agricultural implements; but we are also in advance of every other nation in the use of agricultural machinery. Our use of iron and steel in agriculture takes rank next to their use in the construction and maintenance of railroads. We lead all nations in the manufacture of cut nails and spikes. Having a larger and more rapidly-increasing population than any other country that is noted for its consumption of iron, we are consequently the largest consumers of nails and spikes in the construction of dwellings and public buildings, stores, warehouses, offices, and similar structures. Our extended and varied mining operations consume iron and steel in large quantities. So do our manufactures of scales and balances, letter-presses, burglar-proof and fire-proof safes, sewing-machines, and wagons and carriages. Sewing-machines are an American invention. Considerable quantities of iron or iron and steel are used for sewer and other gratings, street-crossings, iron pavements, lamp-posts, posts for awnings, all sorts of small hardware, horseshoes and horseshoe nails, wire rope, iron hoops, iron cots and bedsteads, woven-wire mattresses, iron screens, iron railings, and fire-arms. In the manufacture of machine and hand tools and general cutlery we are excelled by no other nation, and in the use of machine tools we are in advance of every other nation. In general cutlery our saws and axes especially enjoy a world-wide reputation. Not the least important use to which iron and steel are put in this country is in the extension of the iron industry itself—every blast furnace, rolling mill, or steel works that is erected first devouring large quantities of these products before contributing to their general supply.

In the substitution of steel for iron this country is rapidly progressing, especially in the construction and equipment of its railroads. During the past few years fully two-thirds of all the rails that have been laid on American railroads have been made of Bessemer steel, and at present a still larger proportion of steel rails is required by our railroad companies. On several American railroads the boilers of all new locomotives are now required to be made of steel, and the tendency is toward the exclusive use of steel for locomotive boilers and its general use for stationary and marine boilers. The tires of American locomotives are now made exclusively of steel, and the fire-boxes of our locomotives are generally made of steel. The steel used in the construction of American locomotives is now chiefly produced by the open-hearth process. We have built a few steel bridges, but there is no marked tendency to substitute steel for iron in bridge-building. Steel is, however, largely used in the manufacture of wire, including wire-fencing, and for car and carriage axles, carriage tires, fire-arms, screws, and many other purposes. But little steel has yet been used in this country for nails and horseshoes.

Mention has been made of the artistic finish of some of our iron-work, but the subject seems worthy of further notice. It is not only in stove-founding, in the graceful designs of bridges and elevated railways, and in the delicate combination of iron with other materials in the construction and ornamentation of buildings that American iron-workers have displayed an exquisite taste and a bold and dexterous touch. The fine arts themselves are being enriched by the achievements of our ironworking countrymen. An iron foundry at Chelsea, in Massachusetts, has recently reproduced, in iron castings, various works of art with all the fidelity and delicacy of Italian iron-founders. The most delicate antique patterns have been successfully copied. Shields representing mythological groups and classic events, medallions containing copies of celebrated portraits, panels containing flowers and animals, an imitation of a Japanese lacquer tray one-sixteenth of an inch thick, and a triumphal procession represented on a large salver comprise some of the work of the Chelsea foundry. Some of the castings have been colored to represent bronze and others to represent steel, while others again preserve the natural color of the iron. The bronzed castings resemble beaten work in copper. Only American iron is used. The ornamental uses to which art castings of iron may be put are many, and as they can be cheaply produced it may be assumed that a demand will ere long be created for them that will be in keeping with the artistic taste which has been so generally developed in our country during the past few years.

We conspicuously fall behind many other nations in the use of iron and steel for military purposes. We maintain only a small standing army and a small navy, and hence have but little use for iron or steel for the supply of either of these branches of the public service. We are also behind many other nations in the use of iron and steel sleepers for railway tracks. We yet have an abundance of timber for railway cross-ties, and hence do not need to substitute either iron or steel cross-ties. Except possibly as an experiment there is not an iron or steel cross-tie in use in this country. It is a singular fact that we still import many blacksmith's anvils, their manufacture being a branch of the iron business to which we have not yet given adequate attention. Anvils of the best quality are, however, made in this country. A far more serious hiatus in our iron industry is found in the almost total absence of the manufacture of tin plates, the basis of which is sheet iron, as is well known. As we can import the crude tin as easily as we import other commodities, our failure thus far to manufacture tin plates must be ascribed to the only true cause—our inability to manufacture sheet iron and coat it with tin as cheaply as is done by British manufacturers. It is not improbable that tin ore may yet be discovered in our own country in sufficiently large quantities to supply any domestic demand that may be created for its use.

CONCLUSION.

In reviewing the historical pages of this report the most striking fact that presents itself for consideration is the great stride made by the world's iron and steel industries in the last hundred years. In 1788 there were only 85 blast furnaces in Great Britain, most of which were small, and their total production was only 68,300 tons of pig iron. In 1880 Great Britain had 967 furnaces, many of which were very large, and their production was 7,749,233 tons. A hundred years ago there were no railroads in the world for the transportation of freight and passengers. Iron ships were unknown, and all the iron bridges in the world could be counted on the fingers of one hand. Without railroads and their cars and locomotives, and without iron ships and iron bridges, the world needed but little iron. Steel was still less a necessity, and such small quantities of it as were made were mainly used in the manufacture of tools with cutting edges.

The great progress made by the world's iron and steel industries in the last hundred years is as marked in the improvement of the processes of manufacture as in the increased demand for iron and steel products. A hundred years ago all bar iron was laboriously shaped under the trip-hammer; none of it was rolled. Nor was iron of any kind refined at that time in the puddling furnace; it was all refined in forges, and much of it was made in primitive bloomary forges directly from the ore. Nearly all of the blast furnaces of a hundred years ago were blown with leather or wooden bellows by water-power, and the fuel used in them was chiefly charcoal. Steam-power, cast-iron blowing cylinders, and the use of bituminous coal had just been introduced. Less than sixty years ago heated air had not been used in the blowing of blast furnaces, and fifty years ago anthracite coal had not been used in them, except experimentally. Thirty years ago the Bessemer process for the manufacture of steel had not been heard of, and the open-hearth process for the manufacture of steel had not been made a practical success. Thirty years ago the regenerative gas furnace had not been invented. The nineteenth century has been the most prolific of all the centuries in inventions which have improved the methods of manufacturing iron and steel, and which have facilitated their production in large quantities.

The next most important fact that is presented in the historical chapters of this report is the astonishing progress which the iron and steel industries of the United States have made within the last twenty years. During this period we have not only utilized all cotemporaneous improvements in the manufacture of iron and steel, but we have shown a special aptitude, or genius, for the use of such improvements as render possible the production of iron and steel in large quantities. Enterprising and courageous as the people of this country have always been in the manufacture of iron and steel, they have shown in the last twenty years that they have in all respects been fully alive to the iron and steel requirements of our surprising national development. If we had not applied immense blowing engines and the best hot-blast stoves to our blast furnaces our present large production of pig iron would have been impossible. If we had not built numerous large rolling mills we could not have had a sufficient supply of plate iron for locomotive and other boilers, the hulls of iron ships, oil tanks, nails and spikes, and other important uses; nor of sheet iron for stoves and domestic utensils; nor of tee, angle, and channel iron for bridge-building and general construction purposes; nor of iron rails for our railroads; nor of bar iron and rod iron for a thousand uses. If we had not promptly introduced the Bessemer process the railroads of the country could not have been supplied with steel rails, and without the four and a half million tons of American steel rails that have been laid down in the past twelve years our trunk railroads could not have carried their vast tonnage of agricultural and other products, for iron rails could not have endured the wear of this tonnage. If we had not established the manufacture of crucible steel and introduced the open-hearth process there would have been a scarcity of steel in this country for the manufacture of agricultural implements, springs for railway passenger cars, tires for locomotives, etc. Foreign countries could not in late years have supplied our extraordinary wants for pig iron, rolled iron, iron and steel rails, and crucible and open-hearth steel, for, if there were no other reasons, the naturally conservative character of their people would have prevented them from realizing the magnitude of those wants. If our iron and steel industries had not been developed in the past twenty years as they have been it is clear that our railroad system could not have been so wonderfully extended and strengthened, and without this extension of our railroads we could not have produced our large annual surplus of agricultural products for exportation, nor could our population have been so largely increased by immigration as it has been.

We cannot fully comprehend the marvelous nature of the changes which have taken place in the iron and steel industries of this country in recent years unless we compare the early history of those industries with their present development.

In Alexander Hamilton's celebrated *Report on the Subject of Manufactures*, presented to Congress on the 5th of December, 1791, just ninety years ago, it was stated with evident satisfaction that "the United States already in a great measure supply themselves with nails and spikes," so undeveloped and primitive was our iron industry at that time. In the preceding year, 1790, Morse's *Geography* claimed, in a description of New Jersey, that "in the whole state it is supposed there is yearly made about 1,200 tons of bar iron, 1,200 ditto of pigs, and 80 of nail rods," and in 1802 it was boastingly declared in a memorial to Congress that there were then 150 forges in New Jersey, "which at a moderate calculation would produce twenty tons of bar iron each annually, amounting to 3,000 tons."

In 1880 there were several rolling mills in New Jersey and several hundred in the United States which could each produce much more bar iron in a year than all of the 150 forges of New Jersey would produce in 1802.

Less than fifty years ago the American blast furnace which would make four tons of pig iron in a day, or 28 tons in a week, was doing good work. We had virtually made no progress in our blast-furnace practice since colonial days. In 1831 it was publicly proclaimed with some exultation that "one furnace erected in Pennsylvania in 1830 will in 1831 make 1,100 tons of pig iron." But, as George Asmus has well said, "a time came when men were no longer satisfied with these little smelting-pots, into which a gentle stream of air was blown through one nozzle, which received its scanty supply from a leather bag, squeezed by some tired water-wheel." After 1840 our blast-furnace practice gradually improved, but it was not until about 1865 that any furnace in the country could produce 150 tons of pig iron in a week. Ten years later, in 1875, we had several furnaces which could each make 700 tons of pig iron in a week; in 1880 we had several which could each make 1,000 tons in a week; and in 1881 we had one furnace which made 224 tons in a day, 1,357 tons in a week, and 5,598 tons in a month.

In 1810, seventy years ago, we produced only 917 tons of steel, none of which was crucible steel. In 1831, fifty years ago, we produced only about 2,000 tons of steel, not one pound of which was crucible steel of the best quality. So imperfect were our attainments as steelmakers in 1831 that we considered it a cause of congratulation that "American competition had excluded the British common blister steel altogether." In 1880 we had virtually ceased to make even the best blister steel, better steel having taken its place, and in that year we produced 1,247,335 gross tons of steel of all kinds, 64,664 tons of which was crucible steel. Our production of Bessemer steel and Bessemer steel rails in 1880 was larger than that of Great Britain.

It was not until 1844 that we commenced to roll any other kind of rails than strap rails for our railroads, and not even in that year were we prepared to roll a single ton of T rails. In 1880 we rolled 1,305,212 gross tons of rails, nearly two-thirds of which were steel rails, and nearly all of which were T rails.

The growth of the iron and steel industries of the United States during the present century is perhaps best exemplified in the statistics of the production of our blast furnaces at various periods. In 1810 we produced 53,908 gross tons of pig iron and cast iron; in 1840 we produced 315,000 gross tons; in 1860 we produced 821,223 gross tons; and in 1880 we produced 3,835,191 gross tons. Our production in 1881 will be about 4,500,000 gross tons.

The position of the United States among iron and steel producing countries in 1880 is correctly indicated in the following table of the world's production of pig iron and steel of all kinds, which we have compiled from the latest and most reliable statistics that are accessible. This table places the world's production of pig iron in 1880 at 17,688,596 gross tons, and the world's production of steel in the same year at 4,343,719 gross tons. The percentage of pig iron produced by the United States was nearly 22, and its percentage of steel was nearly 29.

Countries.	Pig iron.		Unwrought steel.				
				Tons of 2,240 pounds.			
	Year.	Tons of 2,240 pounds.	Year.	Bessemer.	Open-hearth.	Crucible and other kinds.	Total.
Great Britain	1880	*7,749,233	1880	*1,044,382	*251,000	†120,000	1,415,382
United States	1880	*3,835,191	1880	*1,074,262	*100,851	*72,222	1,247,335
Germany, including the Grand Duchy of Luxemburg	1879	*2,397,818	1880	*686,500	†50,000	†40,000	776,500
France	1880	*1,705,249	1880	†300,000	†47,327	*31,118	378,445
Belgium	1880	*586,051	1879	†125,000	†5,000	†5,000	135,000
Austria and Hungary	1880	*448,197	1880	*99,741	*27,194	†5,000	131,935
Russia	1879	*420,865	1879	†153,636	†50,000	*7,368	211,004
Sweden	1879	*336,092	1879	†20,400	†5,718	†2,000	28,118
Other countries	1880	†200,000	1880	....	†15,000	†5,000	20,000
Total	......	17,688,596	......	3,503,921	552,090	287.708	4,343,719

* Official. † Estimated.

Although this country can not produce iron and steel as cheaply as European countries which possess the advantages of cheap labor and proximity of raw materials, it is not excelled by any other country in the skill which it displays or the mechanical and scientific economies which it practices in any branch of their manufacture, while in certain leading branches it has displayed superior skill and shown superior aptitude for economical improvements. Our blast-furnace practice is the best in the world, and it is so chiefly because we use powerful blowing-engines and the best hot-blast stoves, possess good fuel, and carefully select our ores. The excellent quality of our pig iron is universally conceded. Our Bessemer steel practice is also the best in the world. We produce much more Bessemer steel and roll more Bessemer steel rails in a given time by a given amount of machinery, technically termed a "plant," than any of our European rivals. No controversy concerning the relative wearing qualities of European and American steel rails now exists, and no controversy concerning the quality of American Bessemer steel ever has existed. We experience no difficulty in the manufacture of open-hearth steel in the Siemens-Martin furnace, and our steel which is thus produced is rapidly coming into general use side by side with crucible steel. In the manufacture of crucible steel our achievements are in the highest degree creditable. In only one respect can it be said that in its manufacture we fall behind any other country; we have not paid that attention to the manufacture of fine cutlery steel which Great Britain has done. This is, however, owing to commercial and not to mechanical reasons. American crucible steel is now used without prejudice in the manufacture of all kinds of tools, and in the manufacture of carriage springs and many other articles for which the best kinds of steel are required. In the quantity of open-hearth and crucible steel produced in a given time by a given plant we are certainly abreast of all rivals. The largest crucible steel works in the world are those of Park, Brother & Co., at Pittsburgh, Pennsylvania. Our rolling-mill practice is fully equal to the best in Europe, except in the rolling of heavy armor plates, for which there has been but little demand and in the production of which we have consequently had but little experience. The quality of our rolled iron, including bar iron, plate iron, sheet iron, iron hoops, and iron rails, is uniformly superior to that of foreign rolled iron. In the production of heavy forgings and castings, as well as all lighter products of the foundry and machine shop, this country has shown all the skill of the most advanced ironmaking countries in Europe. In the production of steel castings we have exhibited creditable skill and enterprise, and we are in advance of all countries in the regular use of the Bessemer converter for this purpose.

All of our leading iron and steel works, and indeed very many small works, are now supplied with systematic chemical investigations by their own chemists, who are often men of eminence in their profession. The managers of our blast furnaces, rolling mills, and steel works are themselves frequently well-educated chemists, metallurgists, geologists, or mechanical engineers, and sometimes all of these combined. Our rapid progress in increasing our production of iron and steel is not merely the result of good fortune or the possession of unlimited natural resources, but is largely due to the possession of accurate technical knowledge by our ironmasters and by those who are in charge of their works, combined with the characteristic American dash which all the world has learned to respect and admire. The "rule of thumb" no longer governs the operations of the iron and steel works of this country.

A feature of our iron and steel industries which has attended their marvelous productiveness in late years is the aggregation of a number of large producing establishments in districts, or "centers," in lieu of the earlier practice of erecting small furnaces and forges wherever sufficient water-power, iron ore, and charcoal could be obtained. This tendency to concentration is, it is true, not confined to our iron and steel industries, but it is to-day one of the most powerful elements that influence their development. It had its beginning with the commencement of our distinctive rolling-mill era, about 1830. In colonial days and long after the Revolution our ironmaking and steelmaking establishments belonged to the class of manufacturing enterprises described by Zachariah Allen, in his *Science of Mechanics*, in 1829. "The manufacturing operations in the United States are all carried on in little hamlets, which often appear to spring up in the bosom of some forest, gathered around the waterfall that serves to turn the mill-wheel. These villages are scattered over a vast extent of country, from Indiana to the Atlantic, and from Maine to North Carolina, instead of being collected together, as they are in England, in great manufacturing districts." While these primitive and picturesque but unproductive methods could not forever continue, it is greatly to be regretted that our manufactures of iron and steel and other staple products could not have grown to their present useful and necessary proportions unattended by the evils which usually accompany the collection of large manufacturing populations in small areas.

Upon the future prospects of our iron and steel industries it is unnecessary for us to dwell. Our resources for the increased production of iron and steel for an indefinite period are ample, and all other essential conditions of continued growth are within our grasp. We are to-day the second ironmaking and steelmaking country in the world. In a little while we shall surpass even Great Britain in the production of steel of all kinds, as we have already surpassed her in the production of Bessemer steel and in the consumption of all iron and steel products. The year 1882 will probably witness this consummation. We are destined also to pass Great Britain in the production of pig iron. These conditions and results are certainly gratifying to our national pride, for of themselves they assure the ultimate pre-eminence of the United States among all civilized countries. If it is true, as recorded in the second chapter of Daniel, that "iron breaketh in pieces and subdueth all things," the country which produces and consumes the most iron and steel must hold the first rank. When the United States takes the position which it is destined soon to take, as the leading iron and steel producing as well as consuming country, the saying of Bishop Berkeley, that "westward the course of empire takes its way," will receive a new interpretation, for the iron industry, which had its beginning in Asia, and then passed successively to the countries along the Mediterranean, upon the Rhine, and in the north of Europe, will then have made the circuit of the world.

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